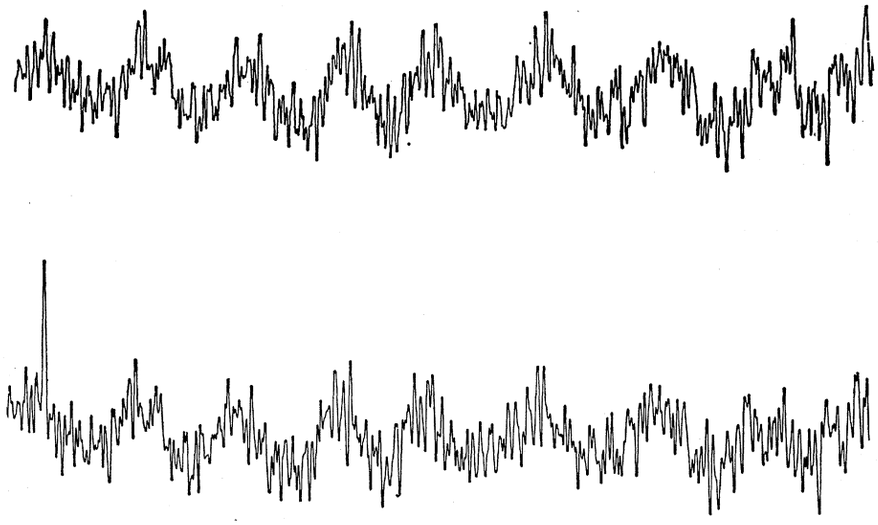

Fig. 1. (Top) An interferometer pattern from the source 3C-294 obtained directly while a recording was being made. (Bottom) An interferometer pattern from the source 3C-294 obtained on playback. The recorded signals were those correlated directly to produce the pattern in the top part of the figure.

recorded from the rubidium standard and a simple counting procedure on the sound track. The synchronizing pulses recorded during the observing period keep the machines locked together to within ± 0.2 μsec. These pulses are then removed from the output of the recorders before further processing takes place. The resulting waveform has blank intervals which reduce the effective observing time by less than 30 percent but which create no other problem.

The first test was performed at a center frequency of 448 Mhz. The antenna system consisted of the 46-m radio telescope and a 10-m instrument located 200 m away. The two local oscillators were *not synchronized*, each being controlled by its own atomic frequency standard. There was no noticeable evidence of any short-term phase drift in the local oscillators.

Two methods of operation were employed during the experiment. In the first mode the local oscillator frequencies were the same and the natural fringe rate resulted. The effective integration time of the system was about 1 second. In this mode strong sources such as Taurus "A" (1200 flux units) produced almost noise-free sinusoidal fringes. The weakest source observed was 3C-294 (4.5 flux units), and the fringes obtained are shown in Fig. 1.

In the second mode of operation the fringe rate was increased to about 300 hertz. This was achieved by offsetting the frequency of one local oscillator with a frequency synthesizer. After the tape recorder outputs were correlated the resulting signal was passed through a narrow filter tuned to the fringe rate and the output of this filter was detected. This mode of operation is particularly useful when searching for a strong source when time at the two stations is not known accurately. We found that with a source such as 3C-273 we could "scan" the tapes for the correct time delay at rates of up to 1 μsec/sec by altering the speed of one machine. A plot of the square of the autocorrelation function of the recorder output, centered at the correct time delay, appeared clearly above the noise.

Since both receivers were at the same site it was possible to correlate the receiver outputs directly while a recording was being made and to compare the fringes thus obtained with the fringes obtained on playback. Figure 1 (top) shows such a record for the source 3C-294 (approximately 4.5 flux units). The signals in this case were passed through the electronics of the tape recorders, bypassing the recording heads but having the "sync." pulses added and subsequently removed. Figure 1 (bottom) shows the results of correlating the same signals after they were recorded on tape and played back at a later time. It is interesting to note that the noise on the two records is strongly correlated, which indicates that most of it is caused by the receiver and not by the tapes.

The use of video tape recorders and atomic frequency standards as a technique for operating two widely separated radio telescopes as a phase-coherent interferometer appears to be quite sound. Synchronizing the two tapes to within a fraction of a microsecond presents no problem. Using tape recorders and unsynchronized local oscillators does not produce a large degradation in the signal-to-noise ratio.

When the system is extended to very long base lines the initial time delay can be taken into account by delaying the recorded timing pulses at one station. Compensation for the variation in the time delay can be accomplished by the simple expendient of varying the speed of one machine. The accuracy required in the alignment of the tapes depends only on the system bandwidth and not on the length of the base line.

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Irradiation Effects in Glasses: Suppression by Synthesis under High-Pressure Hydrogen

Abstract. *Glasses synthesized under high pressure of hydrogen showed resistance to certain effects of irradiation. Paramagnetic and light-absorption effects associated with irradiated glasses were diminished by a factor as large as 20 in some glasses. Irradiation increases the concentration of hydroxyl ions, as evidenced by increased absorption in the 2.7-micron (3700 cm^{-1}) infrared region for hydrogen-silica glasses.*

We have shown previously that various gases may be forced into glasses and melts at high temperature by use of high-pressure techniques (*1*). In this study glasses containing up to 8 moles percent of H_2 were synthesized by the following process: The glass was heated to 800°C under hydrogen at pressures as high as 3 kb; then, when equilibrium

had been achieved, it was quenched, full pressure being maintained until room temperature was reached, whereupon the pressure was released; the resultant glass had H_2 in solution (*2*). When SiO_2 or B_2O_3 glasses are so treated before irradiation with neutrons or gamma rays, electron spin resonance (ESR), ultraviolet, and visible optical absorption due to irradiation, usually observed in the glass, is much less than in untreated and irradiated glass.

Silica glass having (parts per million) 100 Al, 10 Ca, and 10 Mg was chosen so that impurities would not mask the effects peculiar to SiO_2 (*3, 4*). Electron spin resonance first-derivative spectra were taken with a Varian EPR spectrometer operating at a frequency of 9 Gc/sec. Ultraviolet, visible, and infrared spectra were taken on glass plates 2 mm thick with a Beckman DK-2A spectrometer. Separate samples were irradiated with gamma rays exceeding 1 Mrad and with neutrons exceeding $7 \times 10^{16}/cm^3$.

Electron spin resonance signals in the region $g = 2$ were very weak or undetectable in treated or untreated B_2O_3 and SiO_2 glasses before irradiation. After irradiation, all untreated samples showed strong ESR signals in the region $g = 2$, in line with earlier results (*5, 6*). However, samples treated with H_2 before irradiation showed attenuated absorption effects. The sharp line near $g = 2$ in untreated silica glass, induced by 4.5 Mrad of Co^{60} gamma irradiation, was attenuated by factors of 20 and 10 for samples containing 1 and 0.07 mole percent H_2, respectively. Certain other ESR effects that appeared in the silica glass after irradiation, however, were not affected by the H_2 treatment. Similar suppression of the strong, sharp central line occurred when samples of silica glass were treated with H_2 before neutron irradiation at a flux of $7 \times 10^{16}/cm^3$.

With B_2O_3 glass, suppression of the ESR absorption near $g = 2$ was complete after introduction of 8 moles percent of H_2 before irradiation, as far as one could observe. Similar treatment with 6 percent argon did not appreciably suppress the signal.

The slight visible coloration noticed in silica glasses irradiated with neutrons ($7 \times 10^{16}/cm^3$) or gamma rays (140 Mrad) is absent from samples pretreated with 0.001 to 2 percent hydrogen. Coloration due to irradiation is greater in glasses containing larger amounts of impurities. For Vycor glass (SiO_2 containing about 2.9 percent B, 0.02 percent Na, about 1 percent As, and other elements) the coloration is very pronounced; untreated, similarly irradiated samples appear black. Coloration is slightly yellow in similarly irradiated Vycor glasses containing 3 percent hydrogen. Vycor with 0.07 percent H_2 shows a fair amount of coloration, while Vycor containing only 0.001 percent H_2 is about as discolored as the untreated sample.

Absorption in the ultraviolet, caused by irradiation, is also suppressed by pretreatment with hydrogen. Transmission is high for unirradiated silica glass in the range of 210 to 240 mμ, but irradiation with neutrons ($7 \times 10^{16}/cm^3$) or gamma rays (over 140 Mrad) cuts transmission to about 10 percent or less in this range. With the same dose of radiation, silica glass pretreated with 0.07 to 2 percent H_2 transmits about 30 percent or more, indicating that the absorption effect is reduced by the pretreatment. Neutron irradiation of silica glasses with a dose of $1.2 \times 10^{18}/cm^3$ resulted in transmission of only about 30 percent at 300 mμ, 2 percent at 265 mμ, and less than 1 percent at 240 mμ, while treated glass containing 2 percent hydrogen transmitted after irradiation about 80 percent at 300 mμ, 55 percent at 265 mμ, and 35 percent at 240 mμ. Therefore it appears that glasses treated with hydrogen transmit more than 30 times as much ultraviolet light after irradiation than does the reference glass in some instances.

In similar experiments with a series of SiO_2 glasses, pretreatment with 1 percent neon had no effect on absorption.

Concomitant differences were also observed in luminescence behavior of the glasses. When SiO_2 glass, untreated or treated with 1 percent neon, is irradiated and then heated for destruction of color centers, it emits purple light visible to the eye. It is interesting that samples containing hydrogen show no such visible emission when heated after irradiation.

According to Mitchell (*4*), after irradiation silica glass absorbs in the ultraviolet because of the formation of *V* and *F* centers. The ESR signals in irradiated silica have been interpreted as due to the trapping of electrons in oxygen vacancies and to holes trapped in silicon-oxygen bonds (*6, 7*). Our results suggest strongly, therefore, that holes and trapped electrons usually induced by radiation are not present in samples pretreated with hydrogen. The emission normally observed from irradiated glass on heating, and due to the destruction of color centers, does not occur in glasses containing hydrogen, presumably because such centers are not present when the glass is heated.

Infrared spectra close to the 2.7-μ (3700 cm^{-1}) OH absorption band were taken before and after neutron irradiation, from samples either untreated or pretreated with hydrogen, in order to detect the possible reaction of H_2 with SiO_2 to form OH groups. A dose of neutrons as light as $7 \times 10^{16}/cm^3$ caused measurable increase in the hydroxyl absorption, and a dose of $1.25 \times 10^{18}/cm^3$ increased by a factor of 3 absorption in silica glass containing 2 moles percent. In contrast, absorption in the hydroxyl region was not observed in the untreated SiO_2 glass before or after irradiation. Therefore irradiation of glasses containing hydrogen unequivocally results in reaction of hydrogen with silica to increase the formation of OH groups.

We suggest that, during irradiation, reaction of hydrogen with the color centers or their precursors results in their elimination. Our data remain insufficiently quantitative to substantiate the idea that the increase in hydroxyl formation during irradiation is directly proportional to the decrease in concentration of color centers formed, but the effects are parallel.

Glass containing hydrogen may find use for containers and windows and in electronic equipment where the masking effect of irradiation of the glass must be avoided.

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7. Presumably holes are also trapped along boron-oxygen bonds [G. M. Muha, *J. Phys. Chem.* **70**, 1390 (1966)] and aluminum-oxygen bonds (*4*) in impure silica.
8. We thank W. C. Snipes and W. B. White for advice and use of equipment. This research work aided by AEC contract AT(30-1)-2887.

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Ionic Mechanism of Cholinergic Inhibition in Molluscan Neurons

Abstract. *Acetylcholine, the inhibitory transmitter to the so-called* H*-neurons of molluscs, produces its effect by increasing the permeability of the subsynaptic membrane to chloride ions. The change in permeability gives rise to a net influx of this anion, which hyperpolarizes the neuron. The presence of an outward pump of chloride ions is postulated to account for the required electrochemical gradient. The participation of potassium ions in this inhibitory phenomenon was not detected.*

The inhibitory postsynaptic potentials (IPSP's) recorded in the so-called *H*-neurons of molluscs are probably produced by a cholinergic mechanism (*1*) since the iontophoretic application of acetylcholine (ACh) on these neurons produces a transient hyperpolarization (the ACh-potential) which has a reversal potential (E_{ACh}) similar to that of the IPSP's (E_{ipsp}) (*2*). Moreover, both ACh-potentials and IPSP's are blocked by *d*-tubocurarine and atropine (*1*, *2*). Our experiments deal with the ionic mechanisms of the IPSP and the ACh-potential in molluscan *H*-neurons. We have found, at variance with other reports (*3*), that the cholinergic hyperpolarization of these easily recognizable cells is due only to a net influx of Cl^- into the cell, this influx resulting from a specific increase in the membrane's permeability to Cl^-.

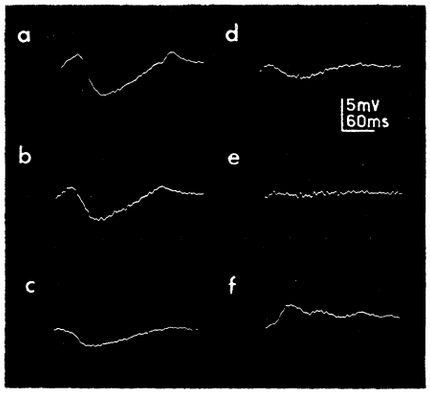

Fig. 1. Dependence on Cl^- of the cholinergic IPSP in an *H*-neuron. In (a) a control IPSP evoked by orthodromic stimulation ($[Cl]_o$ = 115 mmole/liter). The gradual reduction of $[Cl]_o$ to 80 (b), 60 (c), 40 (d), and 20 mmole/liter (e) produced a diminution of the IPSP amplitude. When the Cl-free solution bathed the preparation, the IPSP reversed (f). In all cases E_m equaled –44 mv.

Perioesophagic ganglia of the land snail *Cryptomphallus aspersa* were isolated in saline solution (*4*), and the *H*-neurons were impaled with double-barreled microelectrodes filled with 0.6*M* Na_2SO_4. One of the barrels was used for intracellular recording, the other for applying current to displace the membrane potential (E_m) to desired levels. Acetylcholine was delivered iontophoretically (*5*) from a micropipette filled with 1*M* acetylcholine iodide onto the neuronal cell bodies, which are devoid of synapses. Braking currents were used to prevent drug leakage and possible desensitization of the receptor (*6*). We changed the external concentrations of Cl^- and K^+ to investigate the effects of the IPSP's and the ACh-potential. We lowered the normal concentration of Cl ($[Cl]_o$) in the Ringer's solution (115 mmole/liter) stepwise by replacing Cl^- with SO_4^{2-} without changing the Na concentration; we kept the osmolarity constant by adding sucrose. The concentration of K^+ ($[K]_o$) in the saline was raised from the normal concentration of 4.9 mmole/liter to 15 mmole/liter by the addition of KCl. After every change in the solution the preparation was thoroughly washed with normal saline.

Figures 1 and 2 illustrate in two different *H*-neurons the effects of a stepwise reduction of $[Cl]_o$ on the IPSP's and on the ACh-potential. The control IPSP (Fig. 1a) gradually decreased in amplitude when $[Cl]_o$ was lowered to 80 (Fig. 1b), 60 (Fig. 1c), 40 (Fig. 1d), and 20 mmole/liter (Fig. 1e). A similar change in the amplitude of the ACh-potential was observed when $[Cl]_o$ was decreased (Fig. 2, b and c). The polarities of both the IPSP's and the ACh-potential reversed in a solution free of Cl^- (Fig. 1f and Fig 2d). These effects clearly indicate a participation of Cl^- in cholinergic synaptic inhibition. We obtained additional evidence for the role of Cl^- by changing the Cl^- concentration gradient across the membrane of *H*-neurons by an intracellular injection of NaCl. We did this by allowing current of appropriate polarity to flow between the two barrels of an intracellular twin microelectrode (*7*), one barrel being filled with KCl and the other with Na_2SO_4. Both the ACh-potential and the IPSP became reversed after currents of 50 to 100 na were passed for 60 to 90 seconds. The ACh-potential recovered its initial polarity and amplitude about 90 minutes after the injection was made.

When $[K]_o$ was increased to 15 mmole/liter, the amplitudes of both IPSP and ACh-potential were reduced. This effect might have been caused by either the change in the K gradient across the neuronal membrane or by the reduction of the membrane resistance of molluscan neurons by high $[K]_o$ (*8*, *9*). We could distinguish these two possibilities by investigating the effects of changes in $[K]_o$ on E_{ACh}. The E_{ACh} was obtained by displacing the membrane potential with inward current passed through one of the barrels of the intracellular microelectrode until the E_m at which the ACh-potential reversal was found. In many experiments the amplitude of the ACh-potential was

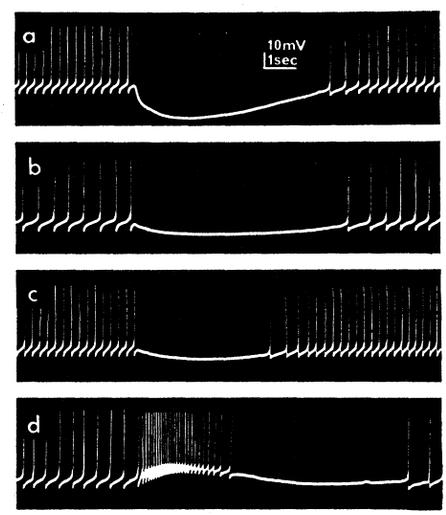

Fig. 2. Effect of changes in $[Cl]_o$ on the ACh-potential in an *H*-neuron. The E_{ACh} was previously measured and found to be –65 mv. (a) Injection of ACh when the cell is bathed in a Ringer solution containing 115 mmole of Cl^- per liter. In (b) and (c) the amplitude of the ACh potential is reduced when $[Cl]_o$ is lowered to 60 and 40 mmole/liter respectively. In (d) the ACh-potential reversed its polarity when the entire Cl^- content of the bathing solution was removed. The initial resting potential of the *H*-neuron [–44 mv in (a)] was slightly modified when some other records were taken, being –46 mv in (b), –44 mv again in (c) and –46 mv in (d).