tween aspartate and glutamate have been seen in *Aplysia*.

In *Aplysia*, the receptors activated by iontophoretic application of serotonin and acetylcholine appear to be identical to those existing at serotonergic and cholinergic synapses, respectively (*14, 15*). Our results suggest that aspartate may also function as a neurotransmitter since there are specific receptors for aspartate which can selectively change the membrane permeability of some neurons to Na^+ or Cl^- (or both).

P. J. YAROWSKY
D. O. CARPENTER
Armed Forces Radiobiology Research Institute, Bethesda, Maryland 20014,
and *Department of Physiology, George Washington University School of Medicine, Washington, D.C. 20015*

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Hydrogen Cyanide Formation over Automotive Catalytic Converters

In a report in *Science* (*1*) Voorhoeve *et al.* discussed laboratory experiments in which substantial amounts of HCN were generated when reactor gas was passed over Pt oxidation catalysts. This topic is significant since many late-model automobiles use Pt alloy oxidation catalysts for the control of CO and unburned hydrocarbon compounds. In addition, the authors point out (*1*): "Future application of catalytic converters for the reduction of NO_x (oxides of nitrogen) is a strong possibility, especially in the remainder of this decade. . . . In some proposed devices for NO_x reduction, a Pt catalyst is used in a reducing exhaust mixture as an oxygen scavenger upstream from the proper NO_x catalyst."

Gould, Inc., manufactures an NO_x reduction catalyst which is similar to the preceding description (*2*). The system is designed to operate at carburetion slightly rich of stoichiometry to provide a net reducing atmosphere. One element of the catalyst system is a Pt alloy, oxygen-removal catalyst situated upstream of the base metal NO_x catalyst bed.

Several comments on the relevance of the data of Voorhoeve *et al.* to an actual automotive exhaust environment can be made. Their reactor feed gas contained 0.5 percent H_2, 5 percent CO, 0.1 to 0.5 percent NO, 0 to 0.006 percent SO_2, and 0 to 3.5 percent H_2O. Although this gas is an approximation to automotive exhaust with very rich carburetion, the correlation is not good. Vehicle exhaust typically contains additional components: 10 percent H_2O, 12 percent CO_2, and 0 to 1 percent O_2. Laboratory data obtained from gas containing these additional components have shown that H_2O, CO_2, and O_2 in the exhaust gas can significantly affect the amount of HCN formed over a Pt catalyst. Moreover, the Pt catalyst tested by Voorhoeve *et al.* promoted complete NO conversion with high selectivity toward NH_3 formation. This particular situation does not occur in a catalyst system where the oxygen-removal catalyst has been treated to eliminate NH_3 formation. The decreased selectivity toward NH_3 formation is observed to influence HCN formation.

We have carried out simulated exhaust gas and actual vehicle testing to check for HCN formation over the NO_x reduction catalyst system. In laboratory testing we used bottled gas with N_2 as the carrier gas. The exhaust gas delivery rate equaled a space velocity of 100,000 $hour^{-1}$. We measured the HCN by bubbling a measured volume of gas through a 0.1*M* KOH solution; the solution was titrated with 0.1*M* $AgNO_3$ with the use of a KI indicator. This technique was insensitive to feed gas moisture and detected HCN in exhaust gas concentrations as low as 0.5 part per million (ppm) with an accuracy of ± 5 percent of the measured value.

The oxygen-removal catalyst used with the NO_x catalyst was an Engelhard PTX-IIB monolith. In some of the experiments we used a PTX catalyst to which a thermochemical treatment had been applied that was effective in suppressing NH_3 formation. The actual NO_x reduction catalyst was the Gould GEM 68 formulation.

The laboratory data are shown in Fig. 1. Curve 1 was measured under the conditions outlined by Voorhoeve *et al.* to maximize HCN formation, that is, 5 percent CO, 0.3 percent NO, and 0.5 percent H_2. The superimposed dashed curve (curve B) represents the data of Voorhoeve *et al.* (*1*) measured under the same conditions except that the curve 1 space velocity was 100,000 $hour^{-1}$ and the curve B space velocity was 14,000 $hour^{-1}$. When 5 percent H_2O (curve 2) is added to the feed gas, the maximum amount of HCN formed decreases from 300 to 30 ppm. When H_2O is adjusted to the 10

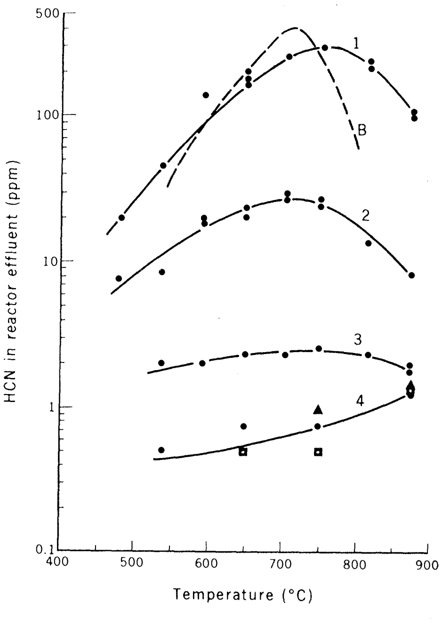

Fig. 1. Formation of HCN over Pt alloy and base metal catalysts: curve 1, PTX in extreme (to maximize HCN formation) exhaust gas containing no H_2O; curve B, data of Voorhoeve *et al.* (*1*) (sponge Pt-II) under conditions similar to those of curve 1; curve 2, PTX in extreme exhaust gas containing 5 percent H_2O; curve 3, PTX in extreme exhaust gas containing 10 percent H_2O; and curve 4, untreated **PTX** (●), treated **PTX** (▲), and GEM 68 (□) in typical synthetic exhaust gas containing 10 percent H_2O.

percent level typically seen in vehicle exhaust gas, the maximum HCN is further decreased to 2 ppm, as shown in curve 3. Curve 4 represents data measured in typical synthetic exhaust gas (1.5 percent CO, 0.5 percent H_2, 12 percent CO_2, 0.1 percent NO, and 10 percent H_2O). Data are given under these conditions for the untreated PTX, treated PTX (for low NH_3 formation), and the base metal GEM 68 NO_x reduction catalyst. At typical catalyst operating temperatures (650°C) in simulated exhaust gas, HCN formation is about 0.5 ppm over the NO_x catalyst system. The data of Fig. 1 clearly indicate that H_2O inhibits the formation of HCN.

Laboratory experimentation has shown that HCN can be formed over a noble metal catalyst under reducing conditions. However, when the gas approximates vehicle exhaust, under net rich carburetion conditions, very little HCN is formed, typically less than 1 ppm. The exhaust gas components that act as HCN promoters are, in order of increasing effectiveness, NO, NH_3, CO, and H_2. On the other hand, the exhaust components that are HCN inhibitors are, in order of increasing effectiveness, CO_2, H_2O, O_2, and SO_2.

Actual vehicle tests have also been conducted to verify the laboratory data and to assess the possibility of the formation of HCN in catalyst-equipped vehicles. A 1975 California Chevrolet Nova (350 cubic inch displaced) was fitted by Gould with a GEM 68 dual-bed catalyst system calibrated to meet the 1978 standards of the Clean Air Act, that is, 3.4 g of CO per mile (2.1 g of CO per kilometer), 0.41 g of hydrocarbon per mile, and 0.4 g of NO_x per mile. The vehicle was operated with an air pump to provide about 5 percent O_2 to the oxidation catalyst and was driven on a chassis dynamometer according to the 1975 Federal Test Procedure schedule (*3*), with Indolene containing 50 ppm of sulfur used as the test fuel. The driving cycle is typical of normal urban driving with accelerations and decelerations giving an average speed of about 25 mile/hour (40 km/hour). In addition to the normal driving mode, a worst-case situation was also simulated when the vehicle was driven at high speed (50 mile/hour) with heavy choke. In the worst-case situation the exhaust contained 6 percent CO and 0.06 percent NO_x. This situation could prevail under heavily loaded driving conditions, for example, a vehicle pulling a trailer uphill. The sampling technique for the vehicle tests was similar to the method used in the laboratory; that is, a measured volume of the tail pipe exhaust was passed through the KOH solution and titrated.

In the normal driving mode, there was no detectable HCN in the vehicle tail pipe emissions. When the car was driven under worst-case conditions, the vehicle exhaust contained 0.5 ppm of HCN, which is the approximate limit of detectability of HCN. These values from the vehicle tests are consistent with the laboratory study indicating a relatively small amount of HCN formed in the routine operation of the dual-bed catalyst system. We did not monitor the HCN concentration of the engine output during the vehicle tests. However, low concentrations of HCN (~ 1 ppm) have been detected in the exhaust of noncatalyst vehicles (*4*).

Thus the ability of an automotive catalytic converter to form HCN is strongly influenced by the chemistry of the exhaust gas. Significant amounts of HCN can be generated in moisture-free or low-moisture gas. When the gas composition is adjusted to approximate typical vehicle exhaust, laboratory data indicate that less than 1 ppm of HCN is formed. Actual vehicle tests have confirmed these laboratory data.

F. M. DUNLEVEY
C. H. LEE
Gould, Inc., Cleveland, Ohio 44108

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