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The Response of the Intoxilyzer 4011AS-A® to a Number of Possible Interfering Substances

REFERENCE: Cowan, J. M., Jr., McCutcheon, J. R., and Weathermon, A., **"The Response of the Intoxilyzer 4011AS-A® to a Number of Possible Interfering Substances,"** *Journal of Forensic Sciences*, JFSCA, Vol. 35, No. 4, July 1990, pp. 797–812.

ABSTRACT: Five Intoxilyzer 4011AS-A®s were tested for their response to eleven chemicals and one mixture of chemicals. The air/water partition ratios were also determined for these eleven chemicals and one mixture. The chemicals tested and their approximate partition ratios were the following: acetaldehyde (190:1), acetone (341:1), acetonitrile (578:1), isoprene (1:1), isopropanol (1671:1), methanol (3229:1), methylene chloride (11:1), methyl ethyl ketone (229:1), toluene (5.5:1), 1,1,1-trichloroethane (14:1), trichloroethylene (20:1), and a 50:50 mixture of 1,1,1-trichloroethane and trichloroethylene (14:1). Of the eleven chemicals and one mixture studied during this experiment, only three, isopropanol, toluene, and methyl ethyl ketone, could reasonably interfere with the test, and then only under unusual circumstances—those circumstances being a slight additive effect to a breath ethanol concentration near the level required for prosecution. Any substantial additive effect from these three substances would illuminate the interference light which invalidates the test. The mean illumination point of the interference light was 0.0286 g/210 L for methyl ethyl ketone, 0.0294 for toluene, and between 0.0116 and 0.0292 for the apparent alcohol concentration for isopropanol, depending on the amount of isopropanol metabolized to acetone. Even with these unusual circumstances considered, the Intoxilyzer 4011AS-A must be viewed as an effective way of determining the ethanol concentration in human breath for evidential purposes.

KEYWORDS: toxicology, intoxication, breath-alcohol testing device, Intoxilyzer

The Intoxilyzer 4011AS-A® (CMI, Inc., Minturn, Colorado) is an instrument designed to measure the ethanol concentration in a vapor sample. The Intoxilyzer 4011AS-A has been certified for evidential use in the State of Texas for a number of years. The Intoxilyzer 4011AS-A has been shown to be a reliable instrument in the forensic science determination of breath alcohol concentration and usually underestimates the venous blood alcohol concentration [*1*].

Despite the proven accuracy and reliability of the instrument, Intoxilyzer 4011AS-A results are sometimes challenged on the premise that some substance other than ethanol was present in the subject's breath sample and that this substance was either solely responsible for producing the apparent ethanol concentration or was responsible for elevating the true ethanol concentration.

The basis for this claim is the assumption that any substance which absorbs infrared

Received for publication 14 April 1989; accepted for publication 28 July 1989.

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energy at 3.48 μm will produce an apparent ethanol concentration since the Intoxilyzer 4011AS-A uses this wavelength to quantitate the ethanol concentration in the vapor sample. This assumption ignores several important factors. In addition to absorbing energy at the 3.48-μm wavelength, any interfering substance must also absorb energy at the 3.39-μm wavelength in approximately the same ratio as ethanol. The Intoxilyzer 4011AS-A compares the ratio of absorption between these two wavelengths. If the interfering substance absorbs in a ratio different from that of ethanol, the instrument will invalidate the analysis by illuminating the interference light and by disabling the instrument's printer [*2*].

There are other factors which must also be considered in determining if a potential interfering substance could effect a breath alcohol analysis, in addition to the substance being capable of reacting with the method of analysis employed. The sample being analyzed is always breath, so the substance must have sufficient vapor pressure to pass from the blood into the breath; the concentration of the interfering substance must be sufficient to cause a significant error in the analysis; and the subject must be physically capable of operating a motor vehicle [*3*].

A number of substances have recently been suggested as possible interfering substances when a person's breath is analyzed by an Intoxilyzer 4011AS-A. It has been suggested that these chemicals could elevate the apparent alcohol concentration and thereby unfairly penalize an individual suspected of driving while intoxicated. The purpose of this experiment was to determine the validity of this suggestion for the following chemicals: acetaldehyde, acetone, acetonitrile, isoprene, isopropanol, methanol, methylene chloride, methyl ethyl ketone, toluene, 1,1,1-trichloroethane, trichloroethylene, and a 50:50, by volume, mixture of 1,1,1-trichloroethane and trichloroethylene. Acetaldehyde results are included in this report; however, these data were obtained in a previous experiment.[3]

Method

Five Intoxilyzer 4011AS-A instruments were specifically prepared and calibrated for this experiment. The exhaust tube on each instrument was rerouted and connected to the inlets on the pump inside the Intoxilyzer. This enabled the vapor from the simulator to be recycled back into solution after it had been analyzed, which greatly reduced the amount of chemical that was depleted by each test. Without this modification, it would have been impossible to obtain accurate and precise results on most of the chemicals tested.

One other problem to be overcome when using an Intoxilyzer 4011AS-A is that the instrument does not start at 0.000 g/210 L even though the display says 0.000. The instrument actually starts at about −0.015 g/210 L, and the reading rises asymptotically, not linearly, up to about 0.070. From 0.070 to 0.480 the instrument's reading is linear. This has the effect of underestimating very low alcohol concentrations. To ensure that a true reading was obtained, all of the solutions prepared had an apparent alcohol concentration of 0.070 g/210 L or higher. The results reported in the tables in terms of apparent alcohol concentrations below 0.070 have been extrapolated back as though the instrument were linear in the 0.000 to 0.070 g/210 L range.

In order to ascertain the vapor concentration of the various chemicals, it was first necessary to determine the air/water partition ratio for each chemical to be tested and the mixture of 50:50 1,1,1-trichloroethane and trichloroethylene. Two different methods were employed on four of the chemicals tested and only one method was employed on the remaining chemicals.

[3]For more details, see "The Effects of Acetaldehyde on Intoxilyzer 4011AS-A Results," by J. Mack Cowan, Jr., and Ronald D. Oliver, presented at the August 1988 Meeting of the Southwestern Association of Forensic Scientists.

The partition ratios for acetone, methanol, isopropanol, and isoprene were first determined by gas chromatograph (GC) (Perkin-Elmer Sigma 2000 gas chromatograph with a Perkin-Elmer LCI integrator). A 6-ft (183-cm), 0.2-mm inside diameter nickle column packed with 5% Carbowax 20M on 60/80 Carbopak B (Supelco Cat. No. 1-1766) and heated to 90°C was used during the experiment. The partition ratio for ethanol was also determined so that the accuracy of the procedure and the results could be evaluated. Water and chemical solutions of 0.05, 0.10, and 0.20 mg/L were prepared for acetone, ethanol, methanol, and isopropanol. Because of its insolubility in water, 0.01, 0.05, and 0.10-mg/L solutions of isoprene were prepared in water solutions containing 0.10 mg/L isopropanol. The samples were prepared by adding appropriate microlitre quantities of analyte and water to a 100-mL volumetric flask. All samples were allowed to equilibrate for at least 30 min at 34°C in a constant-temperature water bath. Three vials for headspace and three vials for liquid analysis were prepared at each concentration for each analyte. Three analyses of the liquid and three analyses of the headspace gas were made at each concentration for a total of nine liquid analyses and nine headspace gas analyses. The liquid samples contained 1 μL and the headspace gas contained 500 μL. All the injections were done manually. For isoprene, the headspace gas samples contained 100 μL and only two 0.01-mg/L samples were obtained, for a total of eight analyses. The areas for each analysis were recorded.

The partition ratios for acetone, acetonitrile, isoprene, isopropanol, methanol, methylene chloride, methyl ethyl ketone, toluene, 1,1,1-trichloroethane, trichloroethylene, and a 50:50 mixture of 1,1,1-trichloroethane and trichloroethylene were determined using an Intoxilyzer 4011AS-A Serial No. 92-001021. The methodology employed in this experiment included the preparation and use of aqueous standards in conjunction with the Tru Test Simulator Model MD 901 (Systems Innovation, Inc. Hollstead, Pennsylvania). The simulator is a simple device designed to maintain a solution of ethanol in water at a constant temperature of 34 ± 0.02°C and deliver a vapor sample containing a predicted concentration of ethanol to a breath-alcohol testing instrument [*4*].

Aqueous standards were prepared for the water-soluble and slightly water-soluble chemicals. A precise amount of chemical was combined with sufficient deionized water to produce a final volume of 6.5 L for each of the following chemicals: acetone (2370 mg/L), acetonitrile (1570 mg/L), isopropanol (1208 mg/L), methanol (1217 mg/L), methylene chloride (1429 mg/L), and methyl ethyl ketone (372 mg/L). Each solution was analyzed five times on the Intoxilyzer 4011AS-A Serial No. 92-001021 and the results recorded.

Aqueous standards were also prepared for the chemicals that are insoluble in water: isoprene, toluene, 1,1,1-trichloroethane, trichloroethylene, and the 50:50 mixture of 1,1,1-trichloroethane and trichloroethylene. However, a slightly different procedure was used.

To ensure that the insoluble chemicals would dissolve as much as possible in water, a small, but precise, amount of each chemical was combined with sufficient 200-proof ethanol to produce a final volume of 100 mL. One millilitre of each ethanol-chemical solution was then pipeted through a port in the top of the MD-901 simulator directly into 500 mL of deionized water at 34°C. The resulting concentration for each chemical tested was as follows: isoprene (1.36 mg/L), toluene (8.67 mg/L), 1,1,1-trichloroethane (53.6 mg/L), trichloroethylene (1171.4 mg/L), and the 50:50 mixture of 1,1,1-trichloroethane and trichloroethylene (112.1 mg/L). These solutions were quickly analyzed only one time on an Intoxilyzer 4011AS-A Serial No. 92-001021, and the apparent alcohol concentration was recorded. This procedure was repeated until five analyses had been performed on each chemical. A precise amount of water equal to the chemical just analyzed was combined with sufficient 200-proof ethanol to produce a final volume of 100 mL. One millilitre of the ethanol-water solution was then pipeted through the port in the top of the MD-901 simulator directly into 500 mL of deionized water at 34°C. The resulting solution was then analyzed five times and the alcohol concentrations were recorded. The alcohol concentration of the ethanol-water analyses was then subtracted from the apparent alcohol concentration of the ethanol-chemical analysis. The five resulting apparent alcohol concentrations, for each chemical, were then recorded.

To determine the concentration of vapor required to result in a specific apparent alcohol concentration on an Intoxilyzer 4011AS-A Serial No. 92-001021 for a chemical other than ethanol, it was necessary to introduce a known concentration of vapor into the sample chamber in the instrument. This was done by allowing microlitre samples of the chemical being analyzed to vaporize in a 1-L Erlenmeyer flask with a side arm. To accomplish this, microlitre samples were injected into a glass tube that passed through an aluminum foil-covered rubber stopper which plugged the top of the flask. In addition, short lengths of Tygon tubing with a set of tubing connectors were placed on the glass tube and the side arm, so the flask could easily be attached to the Intoxilyzer. Prior to injection of the chemicals, hemostats were attached to the Tygon tubing and used as hose clamps to prevent any of the chemical from escaping. The hemostats were removed after the flask was attached to the Intoxilyzer, just prior to the analysis.

The volume of the entire system, which included the volume of the Erlenmeyer flask and its tubing, along with the volume of the Intoxilyzer sample chamber, its tubing, and the internal pump, was experimentally determined by using ethanol as a known standard. One microlitre of 200-proof ethanol was injected into the Erlenmeyer flask and analyzed. The mean of ten analyses for alcohol concentration was 0.0951, with a coefficient of variation of 5.0%. From this figure it was determined that the volume of the flask, tubing, sample chamber, and pump was 1.8026 L. Similarly, a series of five analyses was then conducted on each chemical and the apparent alcohol concentrations were recorded.

A series of five analyses for each chemical was performed on the other four Intoxilyzer 4011AS-A instruments using aqueous standard solutions in a manner identical to the method described above, and the apparent alcohol concentration for each analysis was recorded. Direct injection of microlitre samples into the Erlenmeyer flask assembly was made only on the Intoxilyzer 4011AS-A Serial No. 92-001021.

Results

The air/water partition ratios for acetone, ethanol, isoprene, isopropanol, and methanol were determined by gas chromatography. A total of nine analyses were performed on liquid samples and headspace gas samples for each chemical (eight for isoprene). The area of the liquid sample was divided by the area of the headspace gas sample for each chemical tested. The result was then multiplied by 500 (100 for isoprene) to equalize the difference in the sample sizes. The nine air/water partition ratios (eight for isoprene) for each chemical were then averaged and the coefficient of variation (CV) was calculated. The mean air/water partition ratios and their CV are listed in Table 1.

The air/water partition ratios for acetone, acetonitrile, isoprene, isopropanol, methanol, methylene chloride, methyl ethyl ketone, toluene, 1,1,1-trichloroethane, trichloroethylene, and a 50:50 mixture of 1,1,1-trichloroethane and trichloroethylene were determined by Intoxilyzer 4011AS-A. Alternating analyses were performed on aqueous solutions and vaporized microlitre samples for each chemical. Five analyses were performed on aqueous solutions and five analyses were performed on vaporized microlitre samples for each chemical, and the apparent alcohol concentration of each analysis was recorded. The concentration of the aqueous solutions and the concentration of the microlitre samples for each chemical were then divided by 1000 times the apparent alcohol concentration displayed by the instrument. This produced results in terms of milligrams per litre, equal to 0.001 g/210 L apparent alcohol concentration. Standardizing the con-

TABLE 1—*Air/Water Partition Ratios.*

Substance	Air/Water Partition Ratio Determined by GC[a]	Coefficient of Variation, %	Air/Water Partition Ratio Determined by Intoxication[b]	Coefficient of Variation, %	Air/Water Partition Ratio from the Literature	Air/Water Partition Ratio Used in all Calculations
Acetaldehyde					190:1	190:1
Acetone	357:1	4.5	341.2:1	1.2	341.2:1	341:1
Acetonitrile			578:1	4.3		578:1
Ethanol	2618:1	4.8			2573:1	2573.1
Isoprene[c]	1.4:1	36.3	1:1	11.5		1:1
Isopropanol	1658:1	2.0	1684:1	1.2		1671:1
Methanol	3226:1	5.4	3231:1	1.8		3229:1
Methylene chloride			11:1	2.9		11:1
Methyl ethyl ketone			229:1	1.6	254:1	229:1
Toluene			5.5:1	7.7		5.5:1
111-Trichloroethane			14:1	8.1		14:1
Trichloroethylene			20:1	5.6		20:1
50/50 Mixture of 111-trichloroethane and trichloroethylene			14:1	7.9		14:1

[a] $n = 9$.
[b] $n = 5$.
[c] $n = 8$ and 100 μL headspace for isoprene.

centration in this way allows the air/water partition ratio to be calculated by simply dividing the concentration of the aqueous solution by the concentration of the vaporized microlitre sample. The five air/water partition ratios for each chemical tested were then averaged and their CV were calculated. These results are listed in Table 1.

Also included in Table 1 is the air/water partition ratio found in the literature for acetaldehyde, 190:1. This ratio has been determined experimentally and used by several investigators [5–7]. Table 1 also contains the air/water partition ratio found in the literature for acetone (341.2:1) [8], ethanol (2573:1) [9], and methyl ethyl ketone (254:1) [10]. Finally, Table 1 contains the air/water partition ratios used in the calculations. The literature values were used for calculations involving acetaldehyde and ethanol. The mean value of the ratios determined by gas chromatography and Intoxilyzer were used for isopropanol and methanol. The ratios determined by Intoxilyzer were used for the remaining chemicals.

Table 2 contains the results (range and mean) of the aqueous solutions for all the chemicals analyzed in this experiment by all five Intoxilyzer 4011AS-A instruments. Table 2 also contains the interference light illumination points, range and mean, for all the chemicals tested on all five Intoxilyzer 4011AS-As. Table 3 takes the data listed in Tables 1 and 2 and gives the mean approximate apparent alcohol concentrations that should result on an Intoxilyzer 4011AS-A for the endogenous breath concentrations, the toxic range concentrations, and the highest reported concentrations found in the literature. The highest reported concentrations were often reported as blood concentrations (always in the fatal cases) but have been converted to their breath approximate equivalents for this table.

Figure 1 illustrates the relative response of the Intoxilyzer 4011AS-A to the water-soluble and slightly water-soluble chemicals tested. Figure 2 illustrates the relative response of the Intoxilyzer 4011AS-A to the chemicals tested that are insoluble in water. Ethyl alcohol is included in both figures for comparison.

Discussion

The results of the analyses for all the chemicals tested clearly established that, in sufficient quantity, all of the chemicals produced a reading on the five Intoxilyzer 4011AS-A instruments used in this experiment. This answers the first criterion established in the introduction. The second criterion was that the substance must not activate the interference light, thus invalidating the test. In sufficient concentration, all but two of the chemicals—acetaldehyde and methanol—illuminated the interference light. The last two criteria stated that the concentration of the substance must be sufficient to cause a significant error and that the subject must be physically able to operate a motor vehicle. These last two criteria, along with the fact that some of the chemicals tested yielded significant results prior to illuminating the interference light, require that the potential of these chemicals as interfering substances be evaluated on a chemical-by-chemical basis.

Acetaldehyde

Research by Cowan and Oliver has indicated that acetaldehyde is not present in the breath of an individual in a concentration sufficient to yield an apparent alcohol concentration greater than 0.000 g/210 L unless ethanol is consumed after taking an aldehyde dehydrogenase inhibitor [11]. The highest concentration found in the literature was 12.33 mg/L in blood [12], reported in Table 3 in terms of a breath concentration of 64.9 μg/L. This would be equal to about 64.9 μg/L in breath and would elevate the true alcohol concentration by about 0.0039 g/210 L, an insignificant amount. It is also likely that the individual would appear more ill than intoxicated and would find operating a motor

TABLE 2—*Intoxilyzer 4011AS-A test results.*

Substance	Aqueous Concentration, mg/L	Air/Water Partition Ratio	Gaseous Concentration, mg/L	Apparent Alcohol Concentration, g/210 L[a]		Gaseous Concentration (0.005 Apparent Alcohol Concentration), μg/L	Interference Light Illumination Point, g/210 L[a]	
				Range	Mean		Range	Mean
Acetaldehyde	114	190:1	0.6	0.020–0.047	0.0361	83.03	none	none
Acetone	2370	341:1	6.95	0.120–0.142	0.1262	275.23	0.010–0.013	0.0116
Acetonitrile	1570	578:1	27.2	0.118–0.125	0.1217	1117.56	0.025–0.032	0.0286
Isoprene	1.36	1:1	1.362	0.041–0.052	0.0453	150.4	0.007–0.010	0.0084
Isopropanol	1208	1671:1	0.72	0.097–0.104	0.1013	35.70	0.024–0.031	0.0292
Methanol	1217	3229:1	0.38	0.083–0.090	0.0862	21.87	none	none
Methylene chloride	1429	11:1	127	0.082–0.093	0.0854	7434.82	0.003–0.005	0.0038
Methyl ethyl ketone	372	229:1	1.62	0.092–0.108	0.1004	80.85	0.022–0.034	0.0286
Toluene	8.67	5.5:1	1.576	0.036–0.076	0.0543	145.0	0.016–0.040	0.0294
111-Trichloroethane	53.6	14:1	3.826	0.022–0.043	0.0296	646.2	0.007–0.007	0.0070
Trichloroethylene	1171.4	20:1	58.568	0.039–0.014	0.0256	11457.0	0.021–0.027	0.0240
50/50 Mixture of 111-trichloroethane and trichloroethylene	112.1	14:1	8.009	0.021–0.044	0.0297	1348.3	0.007–0.007	0.0070

[a] $n = 5$.

TABLE 3—*Apparent alcohol concentrations.*

Substance	Endogenous Breath Concentration, ng/L		Apparent Alcohol Concentration, g/210 L	Toxic Range (Breath)	Apparent Alcohol Concentration, g/210 L	Highest Reported Concentration in Terms of Breath	Apparent Alcohol Concentration, g/210 L	Interference Light Illumination Point Mean, g/210 L[a]
	Range	Mean						
Acetaldehyde	2–15	5.5	0.000	8–53.2 µg/L	0.000–0.003	64.9 µg/L	0.0039	none
Acetone	75–225	120	0.000	<300 µg/L	<0.005	19 000 µg/L	0.3452	0.0116
Acetonitrile	7–100	24	0.000	none found	...	100 ng/L	0.0000	0.0286
Isoprene	18–63	33	0.000	none found	...	63 ng/L	0.0000	0.0084
Isopropanol	0.18–7	1	0.000	0.2–1.5 mg/L	...	fatal ~1.5 mg/L	0.3420	0.0292
Methanol	0.1–0.3	0.2	0.000	~30–60 µg/L	0.007–0.014	fatal ~1 mg/L	0.2286	none
Methylene chloride	none reported		0.000	<22.9 mg/L	<0.015	fatal ~46 mg/L	0.0312	0.0038
Methyl ethyl ketone	none reported		0.000	none found	...	54 µg/L	0.0033	0.0286
Toluene	4–18	9	0.000	0.05–1.7 mg/L	0.002–0.059	1.73 mg/L	0.0598	0.0294
111-Trichloroethane	none reported		0.000	<1 mg/L	<0.008	fatal ~720 mg/L	0.3979	0.0070
Trichloroethylene	none reported		0.000	<1.3 mg/L	0.000	fatal ~4.5 mg/L	0.0020	0.0240
50/50 Mixture of 111-trichloroethane and trichloroethylene	none reported		0.000	<1 mg/L	<0.003	fatal 2.6 mg/L	0.0095	0.0070

[a] $n = 5$.

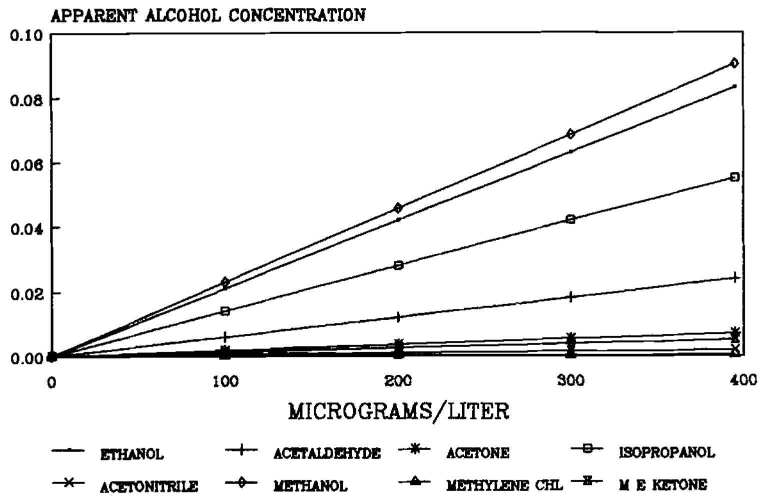

FIG. 1—*Water-soluble possible interferents.*

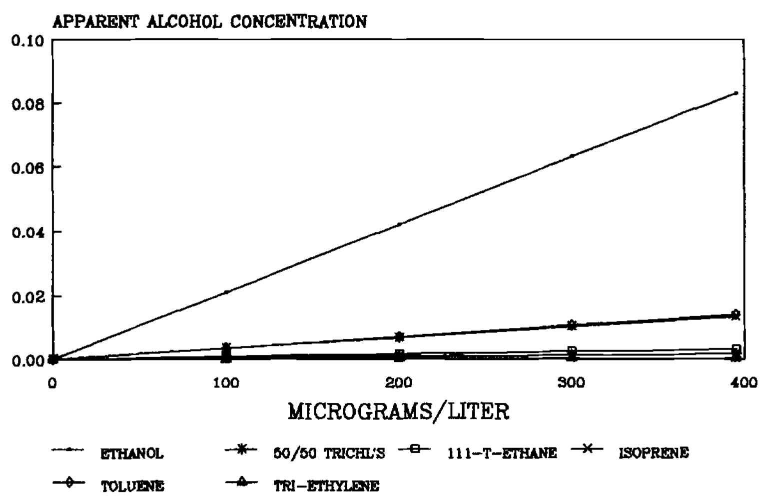

FIG. 2—*Water-insoluble possible interferents.*

vehicle extremely difficult. This view and the view that acetaldehyde does not interfere with infrared breath alcohol analyzers is shared by Jones [*13*].

Acetone

This chemical is not a commonly consumed or inhaled substance; however, it may be present in products that also contain toluene and can be accidentally inhaled by abusers. Acetone can also be found in diabetics who are not taking a sufficient quantity of insulin and in certain dieters who are either fasting or on a high-protein, low carbohydrate diet. Severe toxic effects have been associated with blood concentrations of 200 to 300 mg/L, and a blood concentration of 550 mg/L has been reported in a fatality [*14*]. These blood acetone concentrations would translate into breath acetone concentrations of about 600 to 900 μg/L and 1600 μg/L, respectively. The resulting mean apparent alcohol concentrations for these breath acetone concentrations would be 0.011, 0.016, and 0.029 g/210 L, respectively. The toxic effects of acetone include decreased respiration, pulse, and temperature; dyspnea; stupor; and, in severe cases, death [*15*].

Acetone is the only volatile chemical that could conceivably be in endogenous breath in sufficient concentration to result in a significant apparent alcohol concentration on the Intoxilyzer 4011AS-A. The only persons capable of producing the amount of acetone required to produce a significant reading on the instrument are untreated diabetics in severe acidosis. Researchers Flores and Frank determined that diabetic individuals, as a group, including those under treatment and those untreated diabetics in acidosis, had breath acetone concentrations ranging from 0 to 19 000 μg/L [*16*]. Dieters were found to have breath acetone concentrations ranging from 2 to 303 μg/L and 3 of the 179 dieters tested were diabetics. From these data, the authors conclude that the maximum level of acetone present in the breath of an individual who was either a diabetic or a dieter and who was not hospitalized for high breath acetone concentrations would be approximately 300 μg/L [*16*]. This would translate into a mean apparent alcohol concentration of 0.005 g/210 L on the Intoxilyzer 4011AS-As used in this experiment.

Dubowski and Essary conducted a series of studies on the response of several breath alcohol analyzers to acetone, using the Intoxilyzer 4011AS-A [*8*]. Their results indicate that at the maximum vapor concentration tested, 600 μg/L of acetone, the Intoxilyzer 4011AS-A recorded an apparent alcohol concentration of 0.000 g/210 L.

While this research is valid, no mention was made of the instrument's underestimating at very low apparent alcohol concentrations. As noted in Table 2, 275.23 μg/L of acetone will result in a mean apparent alcohol concentration of about 0.005 g/210 L. If an individual's breath contained no other volatiles, such as ethanol, the Intoxilyzer would display an apparent alcohol concentration of 0.000 g/210 L. However, if the individual had an ethanol concentration of 0.07 or greater, the apparent alcohol concentration would be elevated by 0.005. It is extremely unlikely that a person with a breath acetone concentration of 275.53 μg/L would consume significant amounts of ethanol, and the possibility of this individual operating a motor vehicle under these conditions must be considered even less likely. Therefore, endogenous acetone is not a significant interfering substance with regard to the Intoxilyzer 4011AS-A [*8,16*].

While it would appear extremely unlikely for an unhospitalized person to contain enough endogenous acetone to produce any significant reading on the Intoxilyzer 4011AS-A, it is possible for a person to consume enough acetone or isopropanol, or both, to produce an apparent alcohol concentration. Isopropanol can cause an apparent alcohol concentration if consumed in sufficient quantity. It is mentioned here because isopropanol is largely converted to acetone as it is being oxidized. If a person, by consuming acetone or isopropanol, or if an acidotic diabetic could contain enough acetone in the body to produce an apparent alcohol concentration on the instrument, the interference light will be illuminated if the mean apparent alcohol concentration is elevated by about 0.0116 g/210 L, as indicated in Table 2. Illumination of the interference light invalidates the test.

Acetonitrile

This chemical is very toxic and cases of consumption and inhalation are very rare. It is included in this research because it is reported to be the third largest volatile hydrocarbon in human breath, with a maximum concentration of 100 ng/L of breath [*17*]. This concentration would yield an apparent alcohol concentration of 0.000 g/210 L on an Intoxilyzer 4011AS-A, as given in Table 3, and would have no measurable additive effect on any alcohol concentration. Acetonitrile should not be considered a possible interfering substance.

Isoprene (2-Methyl-1,3-Butadiene)

A number of researchers list isoprene as one of the main volatile hydrocarbons in human breath [*17–19*]. The maximum concentration reported is about 63 ng/L in breath [*17*]. This concentration would yield an apparent alcohol concentration of 0.000 g/210 L, shown in Table 3, and would have no measurable additive effect on any alcohol concentration. It should be noted that isoprene illuminated the interference light at a mean apparent alcohol concentration of 0.0084 g/210 L, a level less than that for acetone. Isoprene should not be considered a possible interfering substance.

Isopropanol

This chemical, commonly referred to as rubbing alcohol, can be consumed in quantities sufficient to yield an apparent alcohol concentration on the Intoxilyzer 4011AS-A. Although it is possible to consume isopropanol, it has a bitter taste and would not be considered potable by the majority. Because of its unpleasant qualities, it is occasionally used as a denaturant in ethanol. If isopropanol is consumed in quantity, the individual will probably suffer from nausea, dizziness, hypertension, flushed face, headache, and mental depression. Increased amounts can cause vomiting, acidosis, coma, and death due to respiratory or cardiac paralysis [*15*]. The toxicity of isopropanol is about twice that of ethanol, and the symptoms of intoxication are similar. The estimated minimum lethal dose is 240 mL, and fatalities have been associated with blood concentrations greater than 1 g/L. Isopropanol is metabolized more slowly than ethanol and is largely converted to acetone, which is slowly excreted from the lungs and in the urine [*14*].

As shown in Table 3, isopropanol is also contained in endogenous breath but at a maximum concentration of 7 ng/L [*17*]; an apparent alcohol concentration of 0.000 g/210 L would result. Endogenous isopropanol would not increase any alcohol concentration in any measurable way. If consumed in sufficient quantity, isopropanol alone would illuminate the interference light at about 0.0292 g/210 L mean apparent alcohol concentration.

The breath of a person who has consumed enough isopropanol to produce a significant apparent alcohol concentration on the instrument would also contain acetone, because acetone is the major metabolite of isopropanol. In a review of 31 fatalities attributed solely to isopropanol poisoning, postmortem blood concentrations ranged from 100 to 2500 mg/L (mean, 1400 mg/L) for isopropanol and 400 to 3000 mg/L (mean, 1700 mg/L) for acetone [*14*]. Depending upon the amount of isopropanol metabolized to acetone, the interference light will be activated at a mean apparent alcohol concentration somewhere between 0.0116 and 0.0292 g/210 L, as indicated in Table 3.

Consumption of isopropanol that results in an arrest for driving while intoxicated (DWI) is rare. A review of more than 20 000 Intoxilyzer test records indicates that only two individuals had apparently consumed enough isopropanol to activate the interference light on an Intoxilyzer 4011AS-A. The presence of isopropanol and acetone along with ethanol was later confirmed in both cases by blood tests performed on a gas chromatograph. While it is rare for an individual to consume an intoxicating quantity of isopropanol, it seems much more likely that such a person would be arrested for DWI and activate the interference light on the instrument than that one would encounter an untreated diabetic in acidosis. The potential interfering effect of isopropanol in combination with ethanol, while quite small, is much more realistic than that of any other substance covered, with the possible exception of toluene.

Methanol

This chemical is also known as wood alcohol and is rarely consumed by human beings. When it is consumed, it is usually done by someone who has mistaken it for ethanol.

Methanol is metabolized by alcohol dehydrogenase much more slowly than ethanol. Initially, methanol's effects are much milder than those of ethanol and the toxic effects are not usually seen until 8 to 36 h after ingestion [*14*]. Methanol has been determined to be additive to the depressant and inebriating effects of ethanol. Some symptoms of methanol toxicity include marked acidosis and motor restlessness, diarrhea, headache, vertigo, blurring of vision, and even blindness [*20*]. The fatal dose varies greatly but is usually between 100 and 200 mL in adults, although ingestion of 30 mL is potentially lethal. Permanent blindness has been caused by as little as 109 mL. Blood methanol concentrations greater than 0.1 g/L (0.01 g/100 mL) are toxic, and blood methanol concentrations greater than 0.2 g/L are indicative of severe poisoning and may be lethal. Postmortem heart and blood concentrations of 0.23 to 2.68 g/L (mean, 1.205 g/L) were found in 15 subjects who consumed contraband "vodka," which was subsequently found to be a mixture of methanol and water [*14*]. Endogenous methanol is reported up to about 0.3 ng/L [*17*], and this concentration would give an apparent alcohol concentration of 0.000 g/210 L and would have no additive effect on any alcohol concentration. Methanol, in sufficient quantity, will produce a positive apparent alcohol concentration on the Intoxilyzer 4011AS-A, but will not illuminate the interference light. As stated above, blood methanol concentrations greater than 0.1 g/L are toxic and concentrations greater than 0.2 g/L are indicative of severe poisoning and may be lethal [*14*]. These concentrations would yield a mean apparent alcohol concentration between about 0.007 and 0.014 g/210 L on the Intoxilyzer 4011AS-A, as given in Table 3. These apparent alcohol concentrations could possibly be significant if added to an ethanol concentration and if the resulting apparent alcohol concentration was at or slightly above the level required for prosecution; however, the possibility of such an individual being well enough to operate a motor vehicle must be considered slight.

Methylene Chloride

This chemical, also known as dichloromethane, is widely used in paint strippers. Death can occur from inhalation alone. Two fatalities are listed in the literature that resulted from methylene chloride inhalation. The postmortem blood methylene chloride concentration of a person who accidentally inhaled the chemical yielded a result of 0.51 g/L, and the postmortem blood methylene chloride concentration of a person who intentionally inhaled the chemical yielded a result of 0.252 g/L [*14*].

In sufficient quantity, methylene chloride will cause a positive apparent alcohol concentration on the Intoxilyzer 4011AS-A. The concentrations listed above would yield mean apparent alcohol concentrations of about 0.031 and 0.015 g/210 L, respectively; however, methylene chloride will also illuminate the interference light. It will illuminate the interference light at a mean apparent alcohol concentration of about 0.0038 g/210 L, as given in Tables 2 and 3. When compared with all of the other chemicals tested, the interference detector was activated at the lowest mean apparent alcohol concentration by methylene chloride. The fact that methylene chloride is so toxic and that it illuminates the interference light at such a low mean apparent alcohol concentration indicates that, by any reasonable standard, methylene chloride is not a potential interfering substance.

Methyl Ethyl Ketone

This chemical, also known as 2-butanone, is used in lacquers, paint removers, cements and adhesives, celluoid, and cleaning fluids. It is also slightly soluble in water. Methyl ethyl ketone is an irritant to the eyes, mucous membranes, and skin. Repeated exposure to high concentrations can cause numbness of the fingers, arms, and legs. Extremely high concentrations may cause symptoms of central nervous system depression, such as dizziness and drowsiness [21]. Perbellini et al. studied a group of workers occupationally exposed to methyl ethyl ketone in the workplace. The workers were exposed to concentrations up to 300 μg/L in the air. Both blood and alveolar breath concentrations of methyl ethyl ketone from this group were studied at the end of the work shift. The blood concentrations ranged between 842 and 9573 μg/L (mean, 2630 μg/L), and the alveolar breath concentrations ranged between 4 and 54 μg/L (mean, 26.4 μg/L) [22]. These alveolar breath concentrations yielded mean apparent alcohol concentrations of 0.000 and 0.003 g/210 L, respectively. The estimated fatal dose is 50 g [23]. The mean illumination point of the interference light for this chemical is 0.0286 g/210 L, as listed in Tables 2 and 3. This chemical could possibly pose a slight problem as a possible interfering substance in an additive way if the individual tested had also consumed enough ethanol to have a combined apparent alcohol concentration at or above a prosecutable level. This possibility is remote, because of the rather low estimated fatal dose and because the apparent alcohol concentration added by this chemical must also be less than the amount required to illuminate the interference light (0.0286 g/210 L), but the possibility must be considered.

Toluene

This chemical is found primarily in paints, lacquer, varnish, and glues. It is also commercially available as a pure solvent. It can and has been abused by individuals who inhale its vapor. Garriott considers the concentration "commonly found in abuse" for toluene to be about 1 to 30 mg/L (mean, 10 mg/L) in blood.[4] The breath/blood ratio for toluene has been experimentally determined to be about 18:1 [24]. The concentration "commonly found in abuse" for toluene in breath is about 0.05 to 1.7 mg/L, as given in Table 3. This will result in an apparent alcohol concentration between about 0.002 and 0.059 g/210 L (mean, 0.019). The highest concentration found in the literature was that of a chronic abuser who had a breath concentration of about 1.73 mg/L [24]. This concentration would result in a mean apparent alcohol concentration of about 0.0598 g/210 L. Trace amounts of toluene, up to 18 ng/L, have been reported in endogenous breath [17]. As with all of the other endogenous volatiles, this concentration would yield an apparent alcohol concentration of 0.000 and would have no additive effect on any alcohol concentration.

Toluene illuminated the interference light on the instruments used in the experiment at a mean apparent alcohol concentration of 0.0294 g/210 L, as shown in Tables 2 and 3. In the state of Texas, a small number of breath tests have been invalidated because of the illumination of the interference light, apparently by the presence of toluene. Subsequent analysis of the blood by gas chromatography indicated that toluene was the only volatile, other than ethanol, in the samples. Toluene could possibly be a significant interfering substance in a case where an individual had also consumed ethanol. This possibility is remote, because the apparent alcohol concentration added by this chemical must also be less than the amount required to illuminate the interference light (0.0294 g/210 L), but the possibility must be considered.

1,1,1-Trichloroethane

This chemical has been found to cause death in blood concentrations of more than 15 mg/L [14], and the postmortem blood concentration of a woman who had a history of "sniffing" was 720 mg/L [25]. The breath concentrations for these blood concentrations

[4]Garriott, J., County of Bexar Office of the Medical Examiner, San Antonio, TX, personal communication, 19 Sept. 1988.

would be about 1 and 51.4 mg/L, respectively. These concentrations would yield mean apparent alcohol concentrations of about 0.008 and 0.3979 g/210 L, as listed in Table 3. The mean illumination point of the interference light for 1,1,1-trichloroethane is 0.007 g/210 L. The low illumination point of the interference light and the fact that a near-fatal dose of this chemical results in an apparent alcohol concentration of 0.008 mean that 1,1,1-trichloroethane should not be considered a possible interfering substance.

Trichloroethylene

This heavy, colorless, toxic liquid is used in degreasing metals, in the refrigeration process, in dry cleaning, and as a fumigant. Therapeutically, it has been used for anesthesia, usually in the range of 26 to 82 mg/L blood trichloroethylene concentration [*14*]. Taking the lower concentration as the maximum point in the toxic range for trichloroethylene, the breath concentration would be about 1.3 mg/L, as given in Table 3. This would result in an apparent alcohol concentration of 0.000 g/210 L. The maximum trichloroethylene concentration found was a postmortem blood concentration of 90 mg/L. This would translate into a breath concentration of about 4.5 mg/L or less, and this would yield a mean apparent alcohol concentration of about 0.002 g/210 L, as shown in Table 3. Obviously, trichloroethylene is not a possible interfering substance.

50:50 Mixture of 1,1,1-Trichloroethane and Trichloroethylene

This mixture of chemicals was chosen for testing because these chemicals comprise the solvent in some liquid typing correction products. These products have been abused by individuals who inhale the solvents. Postmortem blood concentrations of two teenage white males who had been inhaling Liquid Paper produced concentrations of 7.0 mg/L 1,1,1-trichloroethane and 29 mg/L trichloroethylene and 4.0 mg/L 1,1,1-trichloroethane and 19.6 mg/L trichloroethylene [*26*]. According to Garriott, these solvents are commonly seen in inhalant abuse, and deaths are not uncommon. Since the deaths result from cardiac arrhythmia, the lethal, toxic, and abuse levels most likely overlap.[5] The toxic level for these solvents would be less than 10 mg/L in blood or less than 1 mg/L in breath. This would produce a mean apparent alcohol concentration of less than 0.003 g/210 L. Garriott states that a concentration of about 10 mg/L or more in blood would probably be fatal.[6] This would be about 1 mg/L in breath and the apparent alcohol concentration might be as high as 0.003 g/210 L, as given in Table 3. If an individual could withstand twice this level or more and still be capable of operating a motor vehicle, the interference light would be illuminated by this mixture at a mean apparent alcohol concentration of 0.007 g/210 L. The mixture of 1,1,1-trichloroethane and trichloroethylene should not be considered as a possible interfering substance.

It has also been suggested that if one endogenous substance is insufficient to produce a significant apparent alcohol concentration, a large number like the 102 volatiles identified in human breath by Krotosznski et al. [*17*] could, through additive or other means, produce a significant apparent alcohol concentration. From all the analyses conducted, it appears as though concentrations of different substances are additive. There was no indication of one or more chemicals potentiating the effects on another chemical on the Intoxilyzer 4011AS-A. Of the 102 chemicals mentioned above, three major constituents account for 51% of the mean organic contents of the breath of healthy individuals—acetone (120 ng/L), isoprene (33 ng/L), and acetonitrile (24 ng/L) [*17*]. The sum of these chemicals would produce a mean apparent alcohol concentration of about 0.000 003 44 g/210 L on an Intoxilyzer 4011AS-A. Obviously, the other 49% of the endogenous

[5]See Footnote 4.
[6]See Footnote 4.

chemicals are not going to raise the apparent alcohol concentration the thousand times necessary to receive a mere 0.003 g/210 L. The combination of all 102 endogenous volatiles identified in human breath would not cause an apparent alcohol concentration greater than 0.000 and would have no measurable additive effect on any alcohol concentration, the one possible exception being if the individual were a diabetic in severe acidosis.

It should be noted that not all of the Intoxilyzer 4011AS-A instruments yielded the same apparent alcohol concentration or illuminated the interference light at the same point for each chemical tested. This was due to slight variances in the filters. The filters do not allow light to pass through at exactly 3.39 and 3.48 μm. Actually, a small band of light wavelengths centered around 3.39 and 3.48 μm is allowed to pass through the filters [*27*]. The range of the band of wavelengths for a particular filter and how directly these wavelengths are centered around the desired point, along with the relationship between the 3.39-μm filter and the 3.48-μm filter, largely accounts for the variance.

Conclusions

No instrument or chemical procedure used in the laboratory is 100% specific, but this does not mean that the instrument or chemical procedure, when properly utilized, does not produce valid results. The same thing is true for the Intoxilyzer 4011AS-A. Of the eleven chemicals and one mixture studied during this experiment, only three—isopropanol, toluene, and methyl ethyl ketone—could reasonably interfere with the test, and then only under unusual circumstances. Those circumstances result in a slight additive effect to a breath alcohol concentration near the level required for prosecution. Any substantial additive effect from these three substances would illuminate the interference light, which invalidates the test. The mean illumination point of the interference light was 0.0286 g/210 L for methyl ethyl ketone, 0.0294 g/210 L for toluene, and between 0.0116 and 0.0292 g/210 L apparent alcohol concentration for isopropanol, depending on the amount of isopropanol metabolized to acetone. Even with these unusual circumstances considered, the Intoxilyzer 4011AS-A must be viewed as an effective way of determining the ethanol concentration in human breath for purposes of evidence.

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