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# Ion Mobility Spectrometry of Drugs of Abuse in Customs Scenarios: Concentration and Temperature Study

**REFERENCE:** Fytche, L. M., Hupé, M., Kovar, J. B., and Pilon, P., **"Ion Mobility Spectrometry of Drugs of Abuse in Customs Scenarios: Concentration and Temperature Study,"** *Journal of Forensic Sciences*, JFSCA, Vol. 37, No. 6, November 1992, pp. 1550–1566.

**ABSTRACT:** A custom-built ion mobility spectrometer has been used to obtain the IMS spectra of cocaine, heroin, amphetamine sulfate and LSD at different drug concentrations and desorption temperatures. Practical detection limits for these four drugs were obtained as a function of desorber temperature and for heroin as a function of analysis time. Spectral and ionization interferences for each of the four drugs of interest were determined. Spectral interferences by innocuous materials are few; ionization interferences occur only at very high ratios of the mass of innocuous material to that of the drug of interest.

**KEYWORDS:** criminalistics, ion mobility spectrometry, drugs of abuse, customs, gas chromatography-mass spectrometry

The use of ion mobility spectrometry (IMS) for the detection and identification of small amounts of drugs of abuse is well documented. For example, IMS studies have been performed on barbiturates [*1*]; the identification of the ions of cocaine and heroin has been successfully performed in the laboratory using IMS-MS [*2,3*]; similar studies have been done for a number of drugs, including amphetamines [*4*] and opiates [*5*]. These experiments were performed with nanogram amounts of drugs in solution under standard instrumental conditions. Little work has been done on the ion mobility spectra of solid samples, introduced when the ion mobility spectrometer is used as a detection instrument for the presence of drugs hidden in objects or deposited on persons; in these cases, the samples may consist of a few milligrams of the material of interest or a few milligrams of innocuous material which may include small amounts of drugs. Studies of the drugs collected from the hands of subjects have shown that drugs could be analyzed and identified [*6,7*] and that basic substances such as amines may be directly injected, without separation or derivatization steps [*6*].

Previous studies at the Laboratory and Scientific Services Directorate (LSSD) of Canada Customs and in the field have indicated that IMS can be a very useful technique for

Received for publication 23 December 1991; revised manuscript received 12 February 1992; accepted for publication 14 February 1992.

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detecting and identifying cocaine and heroin in submicrogram amounts in the presence of other materials and that very few innocuous materials give spectral interferences with these two drugs [*8,9*].

This study extends the use of IMS to the detection and identification of amphetamine sulfate and LSD and determines the effect of innocuous materials on these drugs. Furthermore, an analysis time and a temperature study have determined the most suitable conditions for the simultaneous detection of four drugs of abuse.

## Experimental Materials and Methods

### *Ionscan 100*

The instrument used in this study was an Ionscan 100 developed by Barringer Research Limited (BRL) in conjunction with LSSD. The Ionscan 100 is the product of further developments on instrumentation used in previous field tests [*9*]. The instrument consists of two main pieces, the detector unit and the pump box.

The detector unit contains an analysis port, the drift tube and detector assembly and all the electronics for the operation of the instrument. The analysis port is made up of a desorber region where the solid sample or solution is placed on a teflon tape and heated to create vapors, and an inlet region for the transfer of the vapors to the drift tube. The temperature of the desorber and the inlet regions and of the drift tube can be controlled by the operator.

The pump box contains the pumps for the carrier and drift gas flows and all the necessary power supplies for the detector. The instrument was used under the operating conditions outlined in Table 1.

Nicotinamide is introduced at all times into the Ionscan 100 as a calibrant ion. The calibration of the channels of interest (one each for cocaine, heroin, LSD and amphetamine sulfate) is performed by introducing the drug, determining the drift time of the peak(s) of interest ($t_i$) and of nicotinamide ($t_n$), calculating the ratio $R_i = t_i/t_n$ and programming the channel by introducing the ratio $R_i$. During the analysis of a sample, the microprocessor searches for a peak at the position $P_i$, where $P_i = R_i * t_n$ where $t_n$ is the position of the nicotinamide peak just before the analysis takes place. The window monitored for each channel is $P_i \pm 0.11$ msec. If a peak is found in any of the windows of interest within the analysis time (4 s for most of the experiments), the microprocessor triggers an audible and a visual alarm.

The microprocessor of the Ionscan 100, as set up in these experiments, sums the data from 16 ion mobility scans of 20 milliseconds to create a spectrum. A number of software conditions must be met in the channel of interest before the instrument triggers the visual and audible alarms [*10*]. When a sample is introduced into the IMS, the signal may rise

TABLE 1—*Instrument conditions for the Ionscan 100.*

| |
|---|
| Desorber Temperature: Varied |
| Inlet Temperature: Varied |
| Drift Tube Temperature: 250°C |
| Voltage: 1430 V |
| Drift tube length: 7.15 cm |
| Analysis Time: 4 seconds, 16 seconds |
| Calibrant Ion: Nicotinamide |
| Width of the Spectrum: 20 milliseconds |
| Drift gas flow: 300 cc/min |
| Sample gas flow: 200 cc/min |
| Drift and sample gas: purified ambient air, |
| 4 channels monitored |

and fall during the analysis period and the identification of a peak requires consideration of the peak amplitude to decide when the response started and when it ended. In ion mobility spectrometry, there are occasional peaks appearing to be no more than roughly Gaussian noise in the baseline; these should be disregarded. These "peaks" are normally present in only one spectrum and they have quite small amplitudes. Thus, the software has constraints to remove these "peaks":

—a peak is identified in a spectrum in a channel if it is within the variability of the expected position of the peak, that is, $P_t \pm 0.11$ msec. This variability is larger than the standard deviation on the peak positions for cocaine and heroin obtained in a previous study (standard deviation of 0.09 msec) [*9*] and should ensure that the peaks will not fall outside this window;

—if a peak is identified in a spectrum and the peak has an estimated amplitude above a certain threshold, then it is a tentative peak;

—in the next spectrum, if a peak is above the threshold and has a peak position close to a tentative peak ($\pm$ 0.08 ms) from the previous spectrum, then it is a true peak; the microprocessor triggers the alarm;

—if no peak is found near a tentative peak in the next spectrum, then the tentative peak is discarded; the alarm is not triggered.

IMS Spectra were collected on an Olivetti M24 Personal Computer using a software package written by Barringer Research Limited [*11*]. The software allows the operator to store spectra for archiving purposes and to calculate the reduced mobility constants for comparison to previously reported values. The IMS spectra of cocaine, heroin, LSD and amphetamine sulfate were collected for a total time of 10.24 s under the IMS conditions described in Table 1.

*Gas Chromatography-Mass Spectrometry (GC-MS)*

Amphetamine sulfate was analyzed by GC-MS under chemical ionization conditions using methane as the ionizing gas. The instrument used was a Kratos MS25RFA mass spectrometer coupled to a Carlo Erba MFC 500 gas chromatograph. The GC-MS conditions used are summarized in Table 2.

LSD was analyzed under the same conditions but using the solid probe instead of the gas chromatograph. The probe temperature was 350°C.

*Calculations*

In ion mobility spectrometry, the separation of ions in the spectrometer is based on differences in the average velocity of ions. The velocity of the ions ($v$) is proportional to the electric field ($E$) used to accelerate the ions towards a collector. The proportionality constant is called the mobility constant, $K$, expressed as:

$$K = v/E = d^2/V * t \text{ cm}^2\ V^{-1}\ \text{sec}^{-1}$$

where $d$ is the drift tube length in cm, $V$ is the potential drop across the drift tube length in volts/cm and $t$ is the drift time in seconds. The time taken for the ions to travel the length of the drift tube is also dependent on the temperature, the pressure and the composition of the drift gas. Reduced mobility constants, $K_o$, corrected for temperature and pressure, are calculated using the following equation:

$$K_o = K * (273/T) * (P/760)\ \text{cm}^2\ V^{-1}\ \text{sec}^{-1}$$

where $T$ is the temperature in Kelvin and $P$ is the pressure in torr.

TABLE 2—*Instrument Conditions for the GC-MS.*

| **Mass Spectrometer** |
|---|
| Scanning range: 40 to 800 amu |
| Scanning rate: 1 second per decade |
| Spectra acquired at 70 eV |
| Ion source: dual ei-ci source held at 150°C. |
| **Gas Chromatograph** |
| DB-5 Fused silica column: |
| 30 meter long |
| 0.25 mm internal diameter |
| 0.25 μm film thickness |
| Carrier Gas: |
| Helium |
| Flow rate 1.2 mL/min. |
| Split ratio: 100:1 |
| Oven program: |
| 80°C held for 2 min |
| ramped to 280°C at a rate of 10°C/min, |
| held for 10 min |
| Injector: 250°C |
| Transfer line: 290°C. |

*Laboratory Equipment*

All masses required were obtained on a Mettler AE200 balance, accurate to the nearest 0.1 mg.

All solutions were transferred with Hamilton Microliter syringes of maximum volume 1.0 μL or 10 μL or with a variable Eppendorf pipette (10 to 100 μL).

*Chemicals*

All samples of cocaine hydrochloride, heroin hydrochloride, amphetamine sulfate and LSD were obtained from the Bureau of Dangerous Drugs, Health and Welfare Canada. The samples were used without further purification.

The samples of interferences were obtained from local grocery stores (spices, vitamins, health products), from LSSD's chemical stores (chemicals), from the Bureau of Dangerous Drugs, Health and Welfare Canada (controlled or illegal substances) or from Astra Pharmaceuticals (lidocaine).

All solvents were reagent grade and were used without further purification.

## Experiments

*Ion Mobility Spectra*

The ion mobility spectra of the four drugs of interest were collected at different desorber temperatures. Spectra were collected on 200 ng of material dissolved in an appropriate solvent. The solution was placed on the filter in the desorber, the solvent allowed to evaporate and the spectrum collected. Spectra were also obtained on 1 mg of material, placed as a solid on the filter.

## Practical Detection Limits

### *1. Definition*

The detection limit of an analytical procedure is regarded as being the lowest concentration of an analyte that can be distinguished from a blank with reasonable confidence. The IUPAC defines the limit of detection as the concentration corresponding to the mean blank signal plus a certain multiple of the standard deviation of the blank, where the multiple 3 is strongly recommended by IUPAC [*12*]. This definition of detection limit requires a knowledge of the response of an instrument as a function of the concentration or mass of the analyte. With this instrument, and in ion mobility spectrometry in general, this response is not known. For this reason, the practical detection limits for the four drugs are defined as the minimum amount of drug detected on each occasion after introducing the sample three consecutive times.

### *2. Temperature Study*

The practical detection limits were determined as a function of desorber temperature. Solutions of cocaine hydrochloride in acetone, heroin hydrochloride in methanol, amphetamine sulfate in methanol and LSD in chloroform were used for these determinations. The desorber and inlet heater temperatures were changed together from 180°C to 300°C in 30°C increments.

The amount of the drug of interest was changed by transferring the proper volume of stock solutions of the drug to the filter in the desorption region and letting the solvent evaporate. One stock solution was used for each drug (5.0 ng/μL for cocaine, heroin and LSD and 1.0 ng/μL for amphetamine sulfate).

### *3. Practical Detection Limits with Silica*

The practical detection limits for the drugs of interest mixed with silica were determined by weighing the proper amount of silica on the sample holder. In order to avoid adding large volumes of the solutions mentioned above, more concentrated stock solutions were prepared in the following way for each drug: for cocaine, 20.25 mg of free base were dissolved in acetone to a final volume of 10 mL (2.025 μg/μL); for heroin, 100 mg were dissolved in methanol to a final volume of 10 mL (10 μg/μL); for LSD, 50 mg were dissolved in 10 mL of chloroform (5.0 μg/μL); for amphetamine sulfate, 50 mg were dissolved in methanol to a final volume of 10 mL (5.0 μg/μL). These stock solutions were diluted, when necessary, to allow the operator to add between 1.0 and 10.0 μL of solution to obtain the proper amount of the drugs. For some of the higher concentrations, volumes between 10 and 100 μL were used. The solvent was evaporated and the analysis performed.

The practical detection limits for the four drugs were obtained at desorber and inlet heater temperatures of 210°C and 300°C, and an analysis time of 4 s.

The practical detection limits for heroin were also determined at desorber and inlet heater temperatures of 300°C and an analysis time of 16 s.

### *Determination of Spectral Interferences*

A number of different substances (139 in total), including drugs, spices, chemical products, vitamins, foodstuffs, toiletry and household products were investigated as possible spectral interferences for the four drugs of interest on the Ionscan 100. The spectral interferences were tested at desorber temperatures of 240, 270 and 300°C. Ten milligrams

of each substance was weighed onto a sample holder and the Ionscan 100 was used to analyze the material.

*Determination of Interferences in the Reactant Region*

Ten milligrams of thirty-two innocuous substances (spices, foodstuffs, cleaning products) were individually mixed with the drug of interest in the amount 2.5 times the practical detection limit of the drug in 10 mg of silica. An analysis was performed at a desorber and inlet temperature of 300°C. If the expected peak was not detected on the Ionscan 100 in the presence of a particular interferent, the analysis was repeated, increasing the amount of the drug of interest until the drug peak was observed. This procedure was repeated for each of the four drugs.

## Results and Discussion

*Ion Mobility Spectra*

Ion mobility spectrometry analyzes samples in the gas phase. Because the vapor pressures of many drugs are low, the first step of the analysis consists of heating the sample to increase the amounts of vapors for eventual detection. In order to avoid condensation of the vapors in the inlet region (a glass tube which allows the vapors to pass from the desorber into the drift tube) and in the drift tube, these pathways were also kept at high temperatures.

The ion mobility spectra of the four drugs of interest were obtained at desorber temperatures of 150, 180, 210, 240, 270 and 300°C, using 200 ng and 1 mg of each material at each temperature. The spectra shown in Figs. 1 through 4 show the average of spectra collected for 10.24 s and stored on a personal computer.

The spectra for LSD are shown in Fig. 1. At a desorber temperature of 150°C (Fig. 1*a*), the peak for LSD at $K_o$ of 1.090 is very small. A more detailed study of the individual spectra indicated that the peak appeared after 5.0 s. Since the analysis time on the IMS was set at 4 seconds, no alarm was obtained on LSD at the desorber temperature of 150°C. When the temperature was raised to 180°C, the peak at $K_o$ of 1.090 appeared after 2.0 s of analysis time. The peak is larger, as shown in Fig. 1*b*. At 210°C, the LSD peak appeared after 0.64 seconds of analysis time. Beginning at 240°C, the LSD peak appeared between 0 and 0.64 s of analysis time. A typical spectrum for those higher temperatures is shown in Fig. 1*c*. Note that the amplitude of the peak has risen sharply from that observed at 180°C. Similar spectra were obtained when one milligram of LSD was analyzed. The peak at $K_o$ of 1.09 is in close agreement with the value of 1.05 obtained previously [*13*]. None of the peaks at higher $K_o$ values (1.16, 1.30 and 1.40) previously seen [*13*] were observed in this study.

The mass spectrum of LSD, using a solid probe at a temperature of 350°C and chemical ionization indicates that a major peak occurs at 323 amu, corresponding to the parent ion of LSD. It has been stated that the ion-molecule reactions that occur in chemical ionization MS can be used to help the prediction of responses in IMS [*14*]. Therefore, the LSD peak at $K_o$ of 1.09 has been tentatively assigned to the parent ion, $M^+$.

The ion mobility spectra for amphetamine sulfate are shown in Figs. 2*a* to 2*c*. At 150°C, using either 200 ng or 1 mg of the drug, the spectrum (Fig. 2*a*) corresponds to that seen by Lawrence [*4*], where the peak at $K_o$ of 1.69 corresponds to the $MH^+$ ion. This agrees with chemical ionization MS which gave a peak at 136 amu. At higher temperatures however, other peaks appear in the ion mobility spectrum. At the lower concentration (200 ng) at 300°C, a peak occurs at $K_o$ of 1.28 (see Fig. 2*b*). At the higher concentration, two peaks with higher drift times were observed at a desorption temperature as low as

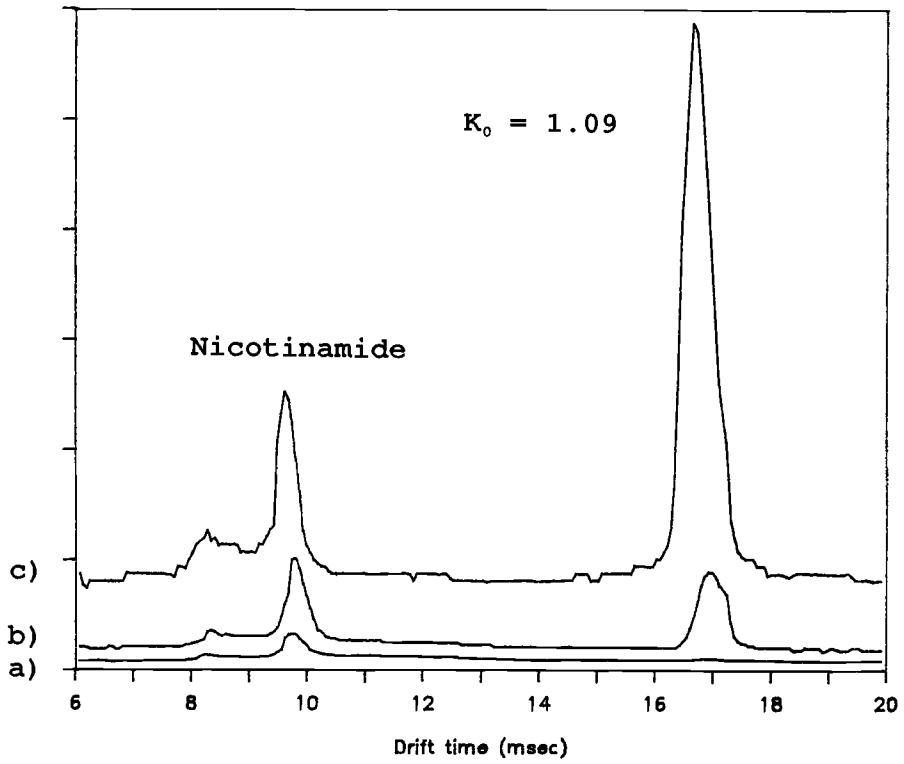


FIG. 1—*Ion mobility spectra of LSD at different desorber temperatures.*

a) spectrum at desorber temperature of 150°C.
b) spectrum at desorber temperature of 180°C.
c) spectrum at desorber temperature of 300°C.

210°C ($K_o$ of 1.28 and 1.11). The spectrum obtained at 300°C is shown in Fig. 2*c*. A GC-MS analysis of the sample indicates that the sample is pure; the peaks at higher drift times at higher concentration are tentatively assigned to cluster formation, because it is known that dimerization and ion-molecule clustering can occur as a result of high concentrations [*5,15,16*].

The ion mobility spectrum of cocaine did not vary with the concentration of the drug or with the desorber temperature. A typical spectrum is shown in Fig. 3. The peak at $K_o$ of 1.17 is in close agreement with values obtained previously for the $M^+$ ion of cocaine [*2,3*].

The ion mobility spectra of heroin are shown in Figs. 4*a* and 4*b*. At 150°C, the spectrum obtained, shown in Fig. 4*a*, is typical of those previously observed, with the peaks at $K_o$ of 1.05 and 1.16 corresponding to the $M^+$ and the $(M-CH_3CO)^+$ ions [*2–4*]. At higher concentration, beginning at 180°C, another peak occurred at $K_o$ of 1.19. At higher temperatures, two other peaks, at $K_o$ of 1.57 and 1.64 (not labeled) also appear (Fig. 4*b*). The identification of these peaks has not yet been attempted.

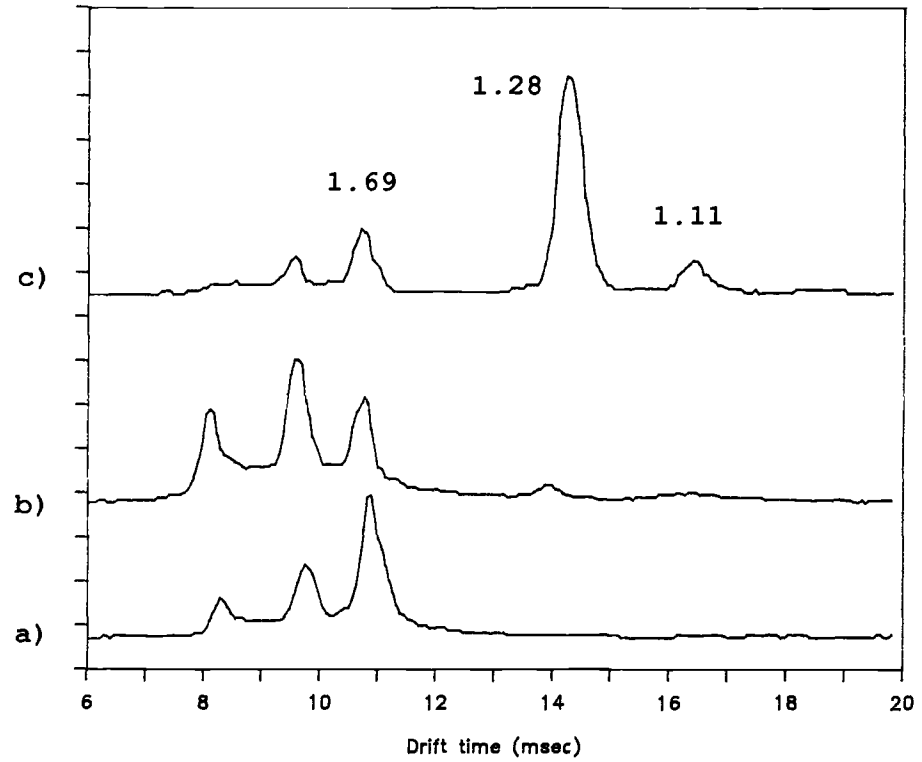


FIG. 2—*Ion mobility spectra of amphetamine sulfate at different desorber temperatures and amphetamine sulfate concentrations.*

a) spectrum at desorber temperature of 150°C, 200 ng of amphetamine sulfate.
b) spectrum at desorber temperature of 300°C, 200 ng of amphetamine sulfate.
c) spectrum at desorber temperature of 300°C, 1 mg of amphetamine sulfate.

In the remainder of the experiments, the Ionscan 100 was used to monitor the parent ion of each drug, since the peaks corresponding to the parent ion were observed at all temperatures and concentrations. One channel was chosen for each drug.

*Practical Detection Limits*

The detection limits were obtained for the four drugs of interest in solutions of an appropriate solvent. The change in the practical detection limits as a function of desorber temperature are shown in Fig. 5 for the four drugs of interest. The limit of detection for heroin reaches its lowest value at 240°C while that for cocaine reaches its lowest value at 210°C. The detection limits for amphetamine sulfate showed little variation with changes in desorber temperature. For LSD, there is a general decrease in the detection limit as the desorber temperature was increased, reaching its lowest value at 300°C, the maximum temperature at which the desorber can be set with this instrument.

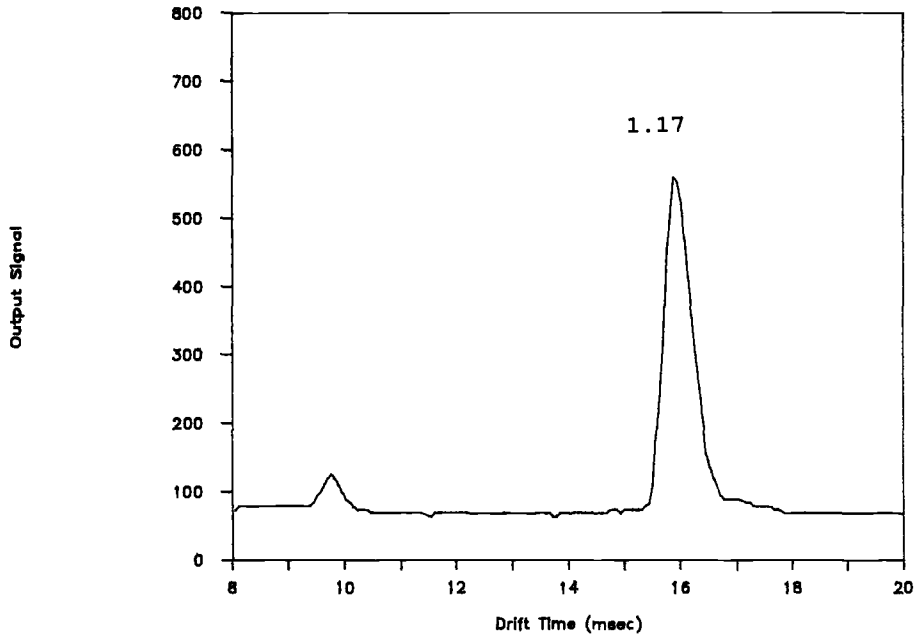


FIG. 3—*Ion mobility spectrum of cocaine.*

To better duplicate the conditions that may be encountered in the field, known amounts of the drugs were mixed with different amounts of solid material. It was found previously, on a prototype instrument at desorber temperatures of 360°C [*9*], and on this instrument at 300°C [*8*], that the presence of a solid mass of material causes an increase in the practical limit of detection of cocaine and heroin; this increase is most likely caused by the slower heating of the solid mass in the desorption area. Silica was used as the solid mass because of its inertness in the IMS.

Similar studies were carried out for LSD and amphetamine sulfate at 300°C and for the four drugs at 210°C. In all cases, there was an increase in the detection limits for the drug with increasing amounts of silica. The detection limits for all the drugs also increased at lower desorption temperatures, as shown in Figs. 6*a* to 6*d*. For these experiments, the analysis time used to determine the presence or absence of the drugs was four seconds, since the instrument was designed for its eventual use by Customs officers in the field where time is often a constraint.

The practical detection limits for heroin were also determined at a desorber temperature of 300°C and an analysis time of 16 s. There is, on average, a 6 fold decrease in the practical detection limit for heroin, as shown in Fig. 7. Close inspection of the ion mobility spectrum of heroin mixed with 100 mg of silica indicates that the heroin peak is visually detected approximately 13.5 s after the beginning of the analysis. This indicates that using a shorter analysis time is not feasible if lower practical detection limits are required. Thus, for heroin, a compromise between analysis time and practical detection limits must be reached by the operator.

*Interferences*

There are two possible types of interferences to the detection of the drugs of interest in ion mobility spectrometry, spectral interferences and ionization interferences.

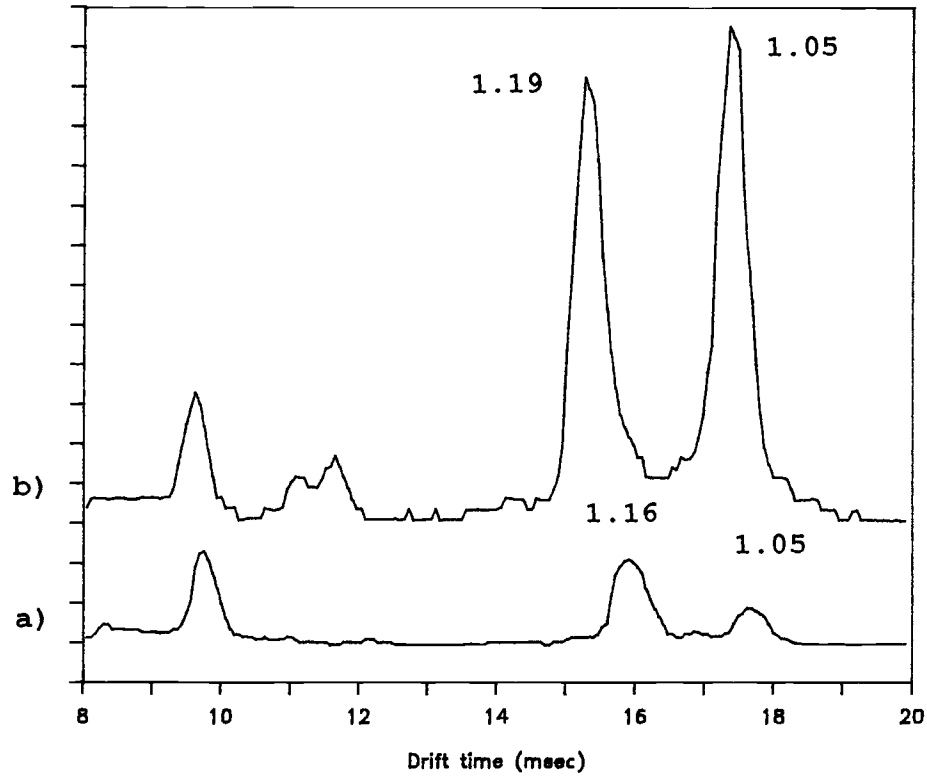


FIG. 4—*Ion mobility spectra of heroin at different desorber temperatures and heroin concentrations.*

a) spectrum at desorber temperature of 150°C, 200 ng of heroin.
b) spectrum at desorber temperature of 300°C, 1 mg of heroin.

*Spectral Interferences*

Spectral interferences occur because a peak caused by an innocuous substance appears in the channel for one of the drugs of interest. The presence of a peak in these channels, within the variability allowed, will cause an alarm. In the absence of the drugs, the peak causes a false positive. The results of some of the spectral interferences obtained for cocaine and heroin at a desorber temperature of 300°C have been reported previously [*8*]. Of 94 substances tested, three caused spectral interferences for the cocaine peak while 6 substances caused a false positive on the heroin channel.

In this study, the list of substances tested was increased to 139. These substances, listed in Table 3, were tested at different desorption temperatures. Of these, only those listed in Table 4 interfered with any one of the four channels monitored. The results shown in Table 4 indicate that lowering the temperature of the desorber does not significantly decrease the number of spectral interferences. Although the number of spectral interferences seems fairly high, a closer look at the substances listed in Table 4 indicates that, in a Customs scenario, many of these interferences do not cause a problem. For example,

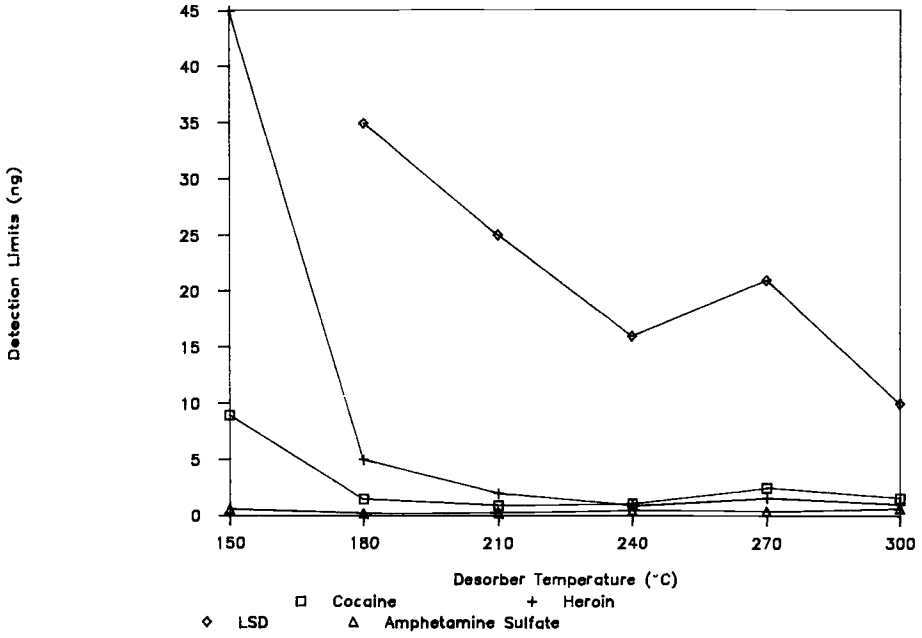


FIG. 5—*Detection limits versus desorber temperature.*

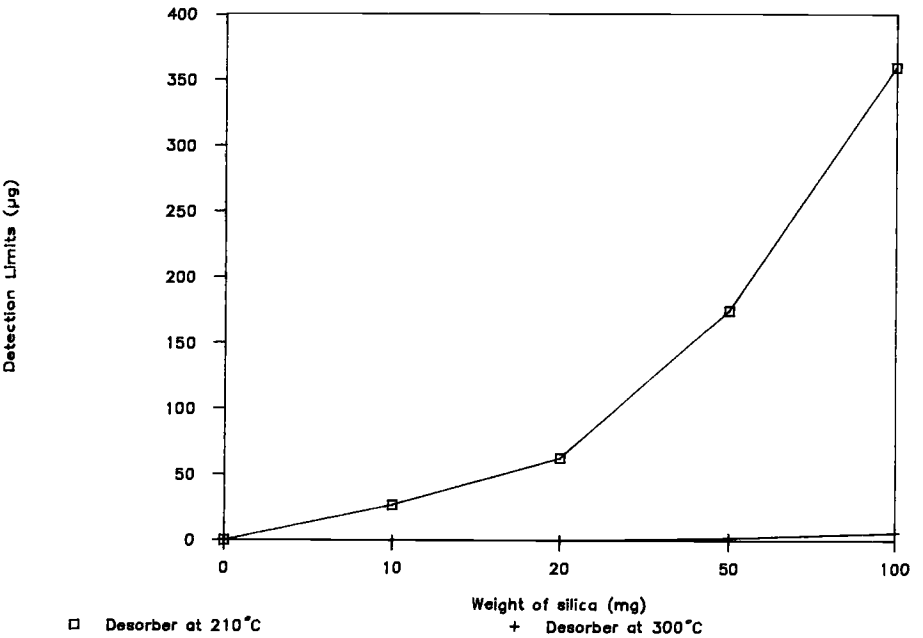


FIG. 6a—*Detection limits of heroin versus weight of silica at different desorber temperatures.*

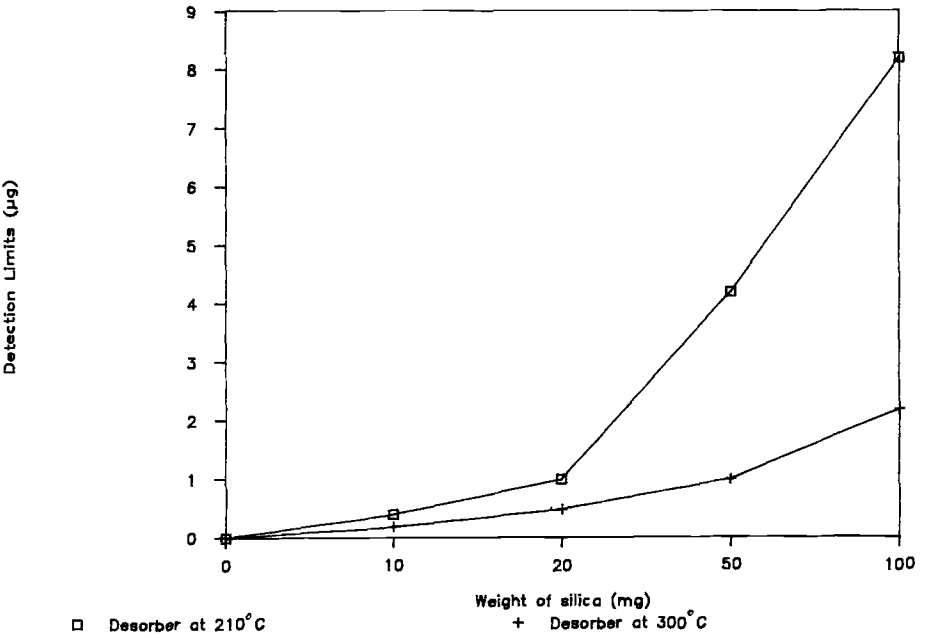


FIG. 6b—*Detection limits of cocaine versus weight of silica at different desorber temperatures.*

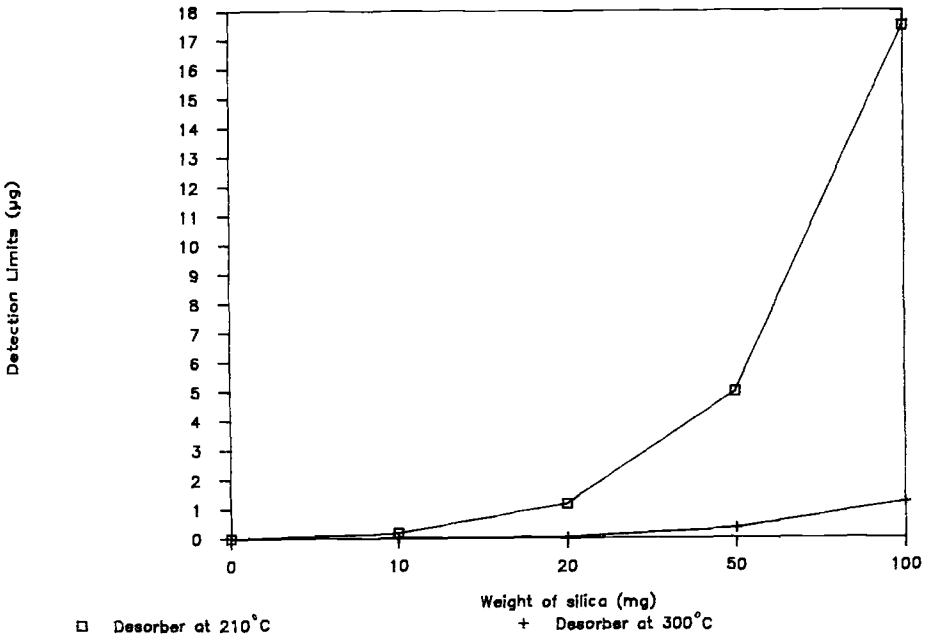


FIG. 6c—*Detection limits of amphetamine sulfate versus weight of silica at different desorber temperatures.*

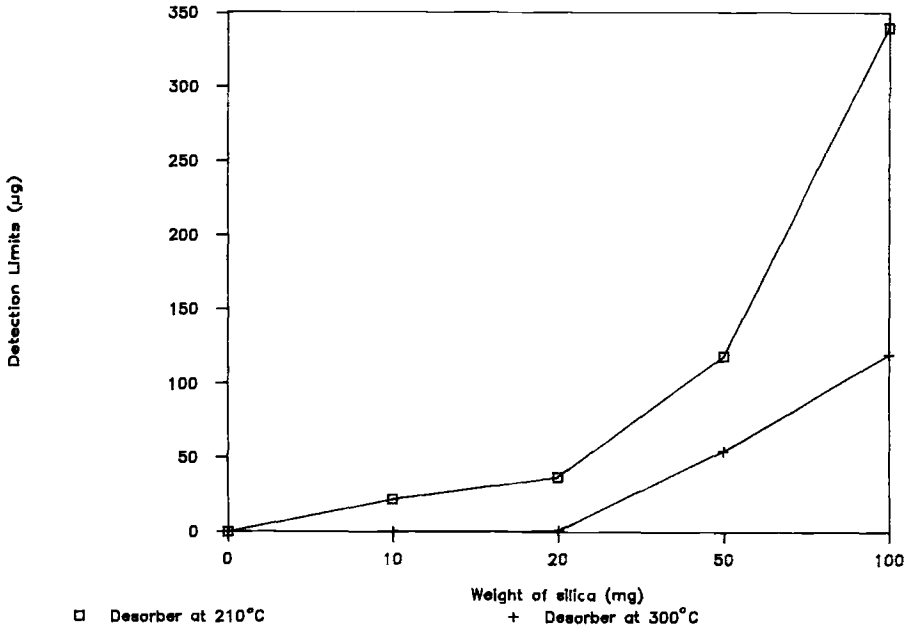


FIG. 6*d*—*Detection limits of LSD versus weight of silica at different desorber temperatures.*

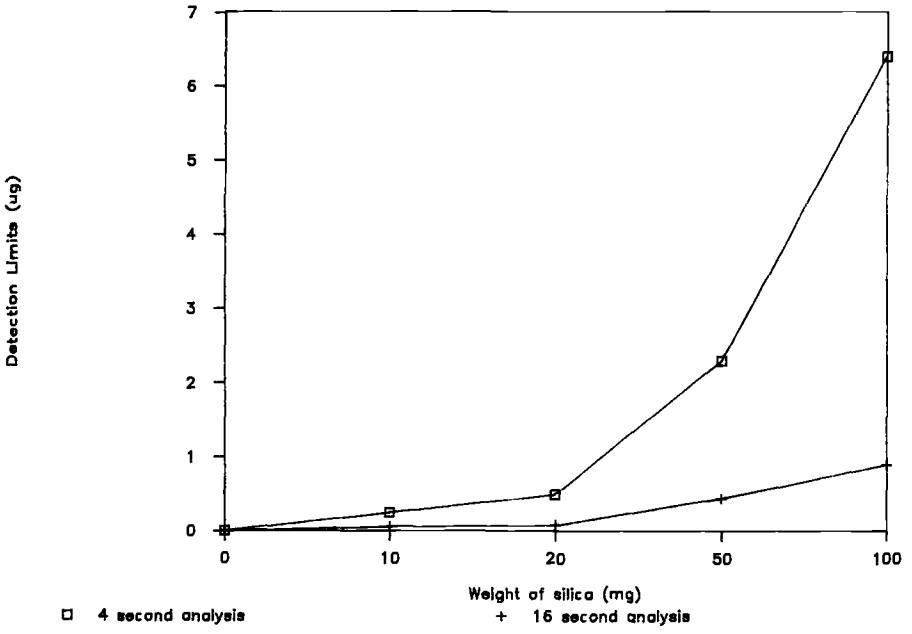


FIG. 7—*Detection limits of heroin versus weight of silica at different analysis times.*

in Canada, opium, marijuana, hashish and THC are governed by the Narcotic Control Act, and mescaline hydrochloride is a restricted drug; thus these substances are of interest to Canadian Customs officials. Ecgonine is obtained from the hydrolysis of cocaine and may be of interest to Customs officers.

Caffeine causes an interference yet a number of different types of coffee (instant, ground, and specialty coffees) did not cause an alarm on the channels monitored. A number of laundry detergents were tested and the majority of these did not interfere with the channels of interest. Marjoram, glycine, lysergamide, butacaine sulfate and paprika are problematic sources of interferences.

### *Ionization Interferences*

The second type of interference in ion mobility spectrometry is the suppression of the peaks of the drugs of interest when the drug is mixed with an innocuous material. The suppression is caused by the ionization of the innocuous material at the expense of the formation of drug ions in the reactant region of the IMS.

TABLE 3—*Substances tested as spectral interferences.*

| | | |
|---|---|---|
| **Drugs** | | |
| Amphetamine | Amphetamine sulfate | Anacin |
| Aspirin | Barbital | Benzocaine |
| Butacaine sulfate | Caffeine (2) | Codeine |
| Ecgonine HCl | Hashish, light (3) | Hashish, dark |
| Hashish oil (3) | Lidocaine | LSD |
| Lysergamide | Lysergic acid | Marijuana, domestic |
| | | Marijuana, Jamaica |
| Marijuana, Columbia | Marijuana, Red Hair | Methadone HCl |
| Mephobarbital | Mescaline HCl | Acetyl morphine |
| Metamphetamine | Methaqualone | Pentobarbital |
| Morphine sulfate | Opium | Procaine |
| Phencyclidine | Phencyclidine HCl | Tetracaine HCl |
| Quinine HCl | Secobarbital | Tylenol |
| THC | Thebaine | |
| **Chemicals** | | |
| Acetyl (p-nitrophenyl) sulphamide | | |
| 2,5-dimethyl-4-(morpholinmethyl)phenol | | |
| 1-Hexadecylpyridinium chloride | | |
| 3-hydroxy-2-naphtoic acid | | |
| 8-hydroxyquinoline sulfate | | |
| 2-mercaptobenzothiazol | | |
| n-propyl-p-hydroxybenzoic acid | | |
| Alanine | Aluminum oxide | Ammonium phosphate |
| Boric acid | Caffeine citrate | Coumarin |
| m-dinitrobenzene | EDTA | Euracylamide |
| Glycine | Irganox-225 | Isoniazide |
| Melamine | Niacinamide | Nicotinamide |
| Phenyl salicylate | 6-methyl coumarin | Nadolol |
| Proparacaine | m-phtalic acid | Pseudococaine |
| Pseudoheroin | Quinidine sulfate | Serine |
| Tannic acid | Tartaric acid | Theophylline |
| o,p-Toluene sulfonamide | | |

TABLE 3—*Continued*

| | | |
|---|---|---|
| **Spices** | | |
| Allspice | Barbecue spice | Basil |
| Cardamom | Cayenne pepper | Celery seeds |
| Cinnamon powder | Coriander | Cumin |
| Curry powder | Dill | Garlic powder |
| Ginger powder | Indian light fennel seeds | Marjoram |
| Mint | Nutmeg | Oregano |
| Paprika | Parsley flakes | Pepper |
| Sage | Summer Savoury | Tarragon |
| Thyme | Turmeric | |
| **Foodstuffs, Vitamins** | | |
| Ascorbic acid | Biotin | Butylated Hydroxyanisole |
| Coffee, instant | Coffee, Columbian | Coffee, Irish Cream |
| Fructose | Glucose | Hot chocolate powder |
| L-proline | Lactose | Perfume |
| Prodoxine HCl | Pyridoxine HCl | Riboflavine |
| Saccharin | Sucrose | Tartaric, Na salt |
| Tea | Thiamine HCl | |
| **Miscellaneous** | | |
| Alconox | Bleaching agent | Cedar |
| Celite powder | Red oak | Scouring powder |
| Silica gel | Talc powder | Tooth paste |
| White oak | Laundry detergents (4) | |

TABLE 4—*Peak interferences in the ion mobility spectrometer.*

| | **Desorber Temperature** | |
|---|---|---|
| 300°C | 270°C | 240°C |
| Caffeine | Caffeine | Caffeine |
| Marjoram | Marjoram | Marjoram |
| Opium | Opium | Opium |
| — | Benzocaine | Benzocaine |
| Marijuana, red hair | Marijuana, red hair | Marijuana, red hair |
| Light Hashish | Light Hashish | Light Hashish |
| Mescaline HCl | — | — |
| THC | — | — |
| Laundry detergent | Laundry detergent | Laundry detergent |
| Ecgonine HCl | Ecgonine HCl | Ecgonine HCl |
| Glycine | Glycine | Glycine |
| Lysergamide | — | Lysergamide |
| Butacaine sulfate | Butacaine sulfate | Butacaine sulfate |
| Paprika | Paprika | — |

Experiments were performed to study the effect of adding large amounts of an interferent to small amounts of the drugs of interest on the IMS signal of the drugs. Ten milligrams of the interferents were used in these experiments. To obtain a reasonable signal for the drugs, the amount of drug added to the interferent corresponded to two and a half times the detection limit of the drug in 10 mg of silica under the same instrument

conditions. If the drug peak was completely suppressed, larger amounts of the drug were added to determine when the Ionscan detected the drug of interest. The interferences tested are listed in Table 5.

A previous study with cocaine and heroin indicated that, of the 33 substances listed in Table 5, 29 of the 33 analyses still indicated the presence of cocaine while only 13 of the 33 analyses still indicated the presence of heroin [*8*]. The weight of the interfering material exceeded the weight of cocaine in the ratio of 20 000:1 (10 mg of interferent and 500 ng of cocaine). In this study, when the amount of cocaine was increased to 1 μg (ratio of 10 000:1), the Ionscan gave an alarm on the cocaine peak. In the case of heroin, in the previous study [*8*] the ratio of interferent to heroin was 15 000:1 (10 mg of interferent and 650 ng of heroin); when the ratio was lowered to 100:1 the Ionscan 100 showed the peak of interest for heroin, except for two substances, L-proline (ratio of 17:1) and quinine HCl (ratio of 25:1).

A similar study was performed with LSD and amphetamine sulfate. Of the 33 substances in Table 5, 31 caused a complete suppression of the amphetamine sulfate peak at a ratio of 133 000:1 (10 mg of interferent and 75 ng of amphetamine sulfate). Decreasing the ratio to 1000:1 showed the amphetamine parent ion peak in all cases except with tarragon, ginger powder (ratio of 500:1), cardamom (100:1) and quinine HCl (10:1). Analyses performed on samples impregnated with LSD in a ratio of interference to LSD of 12 000:1 (10 mg of interferent and 850 ng of LSD), gave alarms on the LSD channel in 26 of 33 cases. Lowering the ratio to 2000:1 showed the LSD peak, except in the case of quinine hydrochloride where the ratio was dropped to 100:1.

## Conclusions

The results of this study show that the Ionscan 100 provides a fast analytical method for the simultaneous detection and tentative identification of cocaine, heroin, LSD and amphetamine, without the need for sample preparation, even in the presence of large amounts of other materials. The detection limits for the drugs studied here are at low microgram levels when mixed with as much as 100 mg of silica. The number of spectral interferences is low and, although there are a number of interferences in the reactant region for the drugs of interest, the results mentioned in this study indicate that the ionization of the substances of interest occurs even when the amount of interferent exceeds by far the amount of the drugs being sought.

*Acknowledgments*

The authors would like to thank Mr. Jacques Hardy for the GC-MS work described in this paper and the various companies and government agencies who provided the

TABLE 5—*Ionization interferences for drugs of interest.*

| | | |
|---|---|---|
| Parsley flakes | Summer savory | Tarragon |
| Thyme | Laundry detergent | Hot chocolate |
| Basil | Celery seeds | Oregano |
| Laundry deterg. ABC | BHA | Dill |
| Cumin | Garlic powder | Allspice |
| Paprika | Marjoram | Aspirin powder |
| BBQ Spice | Cinnamon powder | Instant Coffee |
| Sage | Cayenne pepper | Quinine HCl |
| Ginger powder | Curry powder | Nutmeg |
| Anacin | Cardamom | Turmeric |
| L-proline | Coriander | Indian light fennel seeds |

chemical substances used in the tests. A special note of thanks is addressed to Drs. Lucy Danylewych-May and Ron Jackson of Barringer Research Limited for their helpful comments and discussions.

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