CHAPTER 6

Ion Mobility Spectrometry

Many of today's CWA detection devices are based on ion mobility spectrometry (IMS), which separates ions based on their different drift velocities in an electric field. Besides being used to detect CWAs, IMS has also been widely used to detect explosives and illicit drugs. Recently, its applications have been expanded to many other areas, including the detection of toxic industrial materials (TIMs).

Theoretically, the time for an ion to drift through an electric field within the drift region under ambient atmospheric condition depends mainly on its shape, mass, and charge. When the strength and length of the electric field are kept constant, the spectrum of an ion's mobility through the drift region is generally referred to as its "signature." A specific ion will have a specific spectrum under specific conditions. Mobility spectra of various ions obtained under controlled conditions are catalogued in libraries residing within the detector. These libraries are used to enable identification of an unknown sample through spectrum matching. Mobility (K) is defined as

$$K\left(cm^2/(V \cdot s)\right) = \frac{v\left(cm/s\right)}{E\left(V/cm\right)} \tag{6.1}$$

where v is the drift velocity of an ion and E is the electric field gradient.

IMS technology has many advantages: rapid analysis, high sensitivity, and low limit of detection (LOD). It does not require any sample preparation in most circumstances, particularly gas samples. For vapor samples, the LOD for most CWAs is at parts-per-billion (ppb) to low parts-per-million (ppm) levels within a few seconds. For solid or liquid samples, as little as a few nanograms (10^{-9} g) of a chemical can be detected.

IMS is a nonselective technology, but with high identification power due to its ability to separate different ions in the drift tube. This is a great advantage over other nonselective techniques. Thus, it can detect a wide range of chemicals and identify them. Most IMS instruments are made to operate under atmospheric conditions.

They do not require the use of additional carrier gases, vacuum pumps, or specialized power supplies. Most field-portable instruments use a weak radioactive ionization source to provide the ionization energy. These features significantly simplify the instrumentation and permit detector miniaturization for field operations. This technique has received a great deal of attention and its application is being rapidly expanded.

6.1 PRINCIPLE OF OPERATION

Figure 6.1 shows a diagram showing the operational principle of IMS detection. The process includes sample introduction, ionization, ionic drift, collision and diffusion, ion collection, and signal generation. Sample vapor is drawn into the detector via the inlet into the ionization region. Many detectors use a membrane barrier to limit the entry of moisture into the drift cell. Some detectors eliminated such membrane to achieve faster responses. Molecules in the vapor sample become ionized by the ionization source to form positive and negative ions according to the physical and chemical properties of the individual molecule. This ionization process occurs under atmospheric conditions. Various ionization sources may be used: radioactive, UV, electron spray, or corona discharge. The use of a radioactive source is by far the simplest and most common. Either positively or negatively charged ions enter the drift tube with an electrical field gradient within a very short time gap (microseconds). While in the drift region, ions of different shapes and sizes formed from a variety of chemicals contained in the vapor sample undergo diffusion and collision with other particles while drifting along the electric field gradient.

6.1.1 Drift

Ions move along the drift tube forced by the electric field gradient applied to the tube. Depending on the strength of the electric field and the shapes and sizes of the ions, the ions will reach the ion collector at other end of the tube at different, but all very short (milliseconds), times.

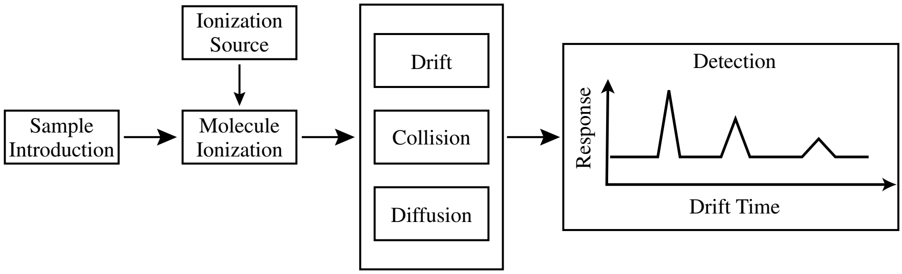

Figure 6.1 Block diagram of ion mobility spectrometer analysis procedure.

Theoretically, force (F, Newton) exerted on the ions resulting from the electrical field (E, volt) applied to a charged particle with a charge of q (Coulomb) is described as

$$F = q \times E \tag{6.2}$$

This force accelerates the ions to move along the electric field gradient toward the ion collector. Positive ions are forced to move from a higher to lower voltage and negative ions move from a lower to higher voltage end of the gradient field. The drift times of ions should be in microseconds for a 10-cm-long electric field with a gradient of 200 V/cm (a typical configuration of drift tubes) when under vacuum. Because the drift tube for IMS detectors is not being operated under vacuum, the observed drift time is actually on the order of milliseconds.

6.1.2 Collision

A drift flow, usually a dried airflow, is normally added in the opposite direction of the ion drift. Since the drift tube is not under vacuum, the ions in the drift tube collide with other molecules in the drift flow. The ions are slowed or stopped by these collisions and then accelerated again by the electric field gradient. This drift-collision-drift process occurs throughout drift time until the ions finally reach the collector. Overall drift time is ultimately controlled by the collision frequency when the electric field gradient is held constant. Ions with larger effective collision cross-sections collide with molecules in the drift flow more frequently than ions with smaller cross-sections. Consequently, overall drift velocity is slower for larger ions. Therefore, larger ions have longer drift times while smaller ions reach the collector earlier. This collision process separates the ions having different collision cross-sections and determines the mobility of the different ions.

6.1.3 Diffusion

In the drift tube, ions also disperse in the tube through diffusion. Diffusion is a concentration gradient–driven process. This diffusion process depends on the nature of the ions and the drift tube temperature that produce the concentration gradient of the ions as they migrate within the tube. The concentration gradient tends to broaden the detection peaks for respective ions in an ion mobility spectrum. This diffusion process is one of the reasons why the longer drift-time ion peaks are broader.

6.1.4 Detection

When the ions eventually reach the ion collector, they lose their acquired charges to the collector, and an electrical current is generated. This electrical signal is being processed to generate the spectrum or other desired formats using a microprocessor. The substance will be reported as detected when the generated information matches the criteria set and stored in the detector's libraries. An audible and/or visible alarm is generated based on the logic used by the instrumentation.

6.2 INSTRUMENTATION OF TYPICAL IMS DETECTOR

A typical configuration for an IMS detector is illustrated in Figure 6.2. The instrument includes sample inlet, ionization region, ion injection gate, drift region, ion collector, and microprocessor.

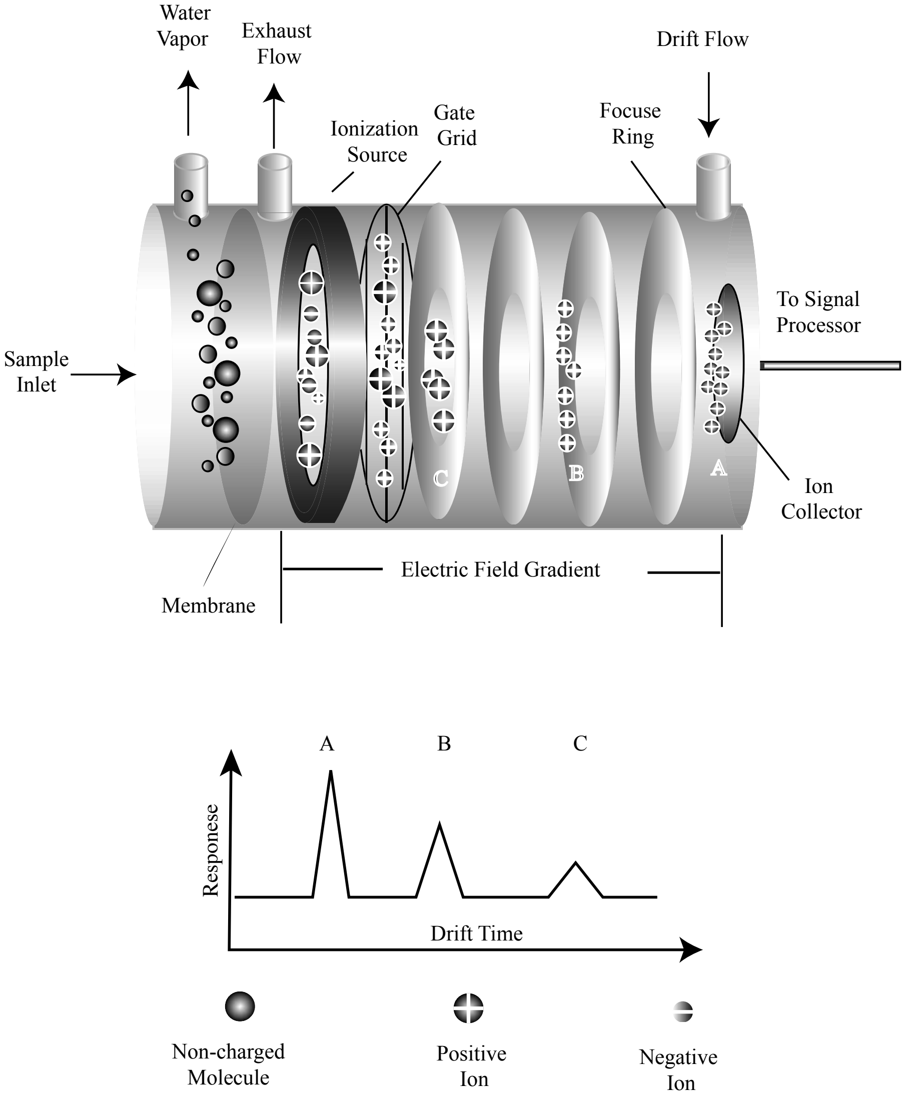

Figure 6.2 Schematic diagram of IMS.

6.2.1 Sample Inlet

The sample to be analyzed enters the detection device through the sample inlet. Its design depends on the type of substances monitored. IMS instruments have been used successfully to analyze CWAs, particulate and vapor samples for illicit drugs, and explosive chemicals. A wiper is used to collect particulate samples by sweeping the surfaces of an object. The swiped sample is heated so that the substances adhering to the swap are vaporized and drawn into the IMS cell for analysis. Similar sampling techniques may also be used for detecting CWA and TIC residues on surfaces. The technique is especially useful for detection of persistent chemicals that have very low vapor pressure. As discussed earlier, these low volatility chemicals are more persistent, and higher concentrations can be found on surfaces where concentrations in the air may be too low for efficient detection.

Most CWAs and high-hazard TICs have relatively high vapor pressure, however. Air contaminated with any of these compounds constitutes a major health risk. Detection of the highly volatile toxic compounds must be done as quickly as possible. The only way this is possible is by direct analysis of the air sample. IMS detectors are designed for this purpose. These detectors can produce very fast responses once the sample reaches the IMS cell. The unknown vapor sample is drawn into these detectors directly without requiring sample preparation. Inlet materials are selected to permit efficient sample transfer. The sample path is generally heated for added sample transfer efficiency.

Moisture content in the sample presents a significant interference problem and reduces IMS detector's identification capability. Commonly, a thin heated membrane that has a low permeation rate for water, such as a dimethylsilicone membrane, is added in front of the IMS ionization region. This membrane is used to limit the amount of moisture that could enter the ionization region to counter the moisture effect while permitting the compounds of interest to permeate. Chemicals in the sample will diffuse through the membrane into the ionization area while most of the water molecules together with other chemicals that also have low permeation rates are carried away by the carrier flow without entering the ionization region. The membrane also serves as a barrier to block dust or other particulate from entering the drift tube.

The use of a membrane, while it reduces the moisture effect, has some disadvantages. The targeted sample must pass through the membrane via the diffusion process before analysis is possible. Diffusion or permeation is a relatively slow process that requires time to reach equilibrium. Therefore, the time to reach the maximum response is longer compared to detectors that do not use a membrane. The membrane can easily become contaminated with dust and other low volatility substances. When that happens, it will require either a long time to clear or maintenance action to replace the membrane. The membrane is very delicate and easily broken. Broken membranes cause the detector to malfunction. Membranes also prevent some of the targeted chemicals from entering the ionization region, which in turn affects detection sensitivity.

6.2.2 Ionization Region

6.2.2.1 Ionization Sources

After diffusing through the membrane, sample molecules enter the ionization region of the detector and become ionized by the ionization source. In most IMS detectors, especially handheld ones, a weak radiation source, $_{28}Ni^{63}$, is used to provide the ionization energy. $_{28}Ni^{63}$, a radioactive isotope of nickel, has a half-life of 100.1 years (National Nuclear Data Center, www.nndc.bnl.gov) and low decay energy of 0.067 meV. $_{95}Am^{241}$ is also used in some detectors as the ionization source. The alpha-decay isotope of americium ($_{95}Am^{241}$) has a half-life of 458 years and decay energy of 5.640 meV. Unlike the flame ionization process, ionization of compounds by $_{28}Ni^{63}$or $_{95}Am^{241}$ does not break the molecules into fragments. Ionization using a radioactive source reduces the signal noise and power consumption of a detector since it does not require electrical power for the ionization process. This greatly simplifies the instrumentation of IMS detectors. Reduced power consumption provides advantages for handheld detectors that must be operated using battery power.

Other ionization sources, such as "corona discharge" and "electron spray" are also used in some IMS detectors. Due to respective limitations compared to the use of a radioactive ionization source, they have not been as widely used in commercialized handheld detectors as those that use a radioactive source. On the other hand, the use of a radioactive ionization source is limited by strict regulatory controls associated with radioactive materials.

$_{28}Ni^{63}$ is a common radioactive source used in many CWA detectors. We discuss its application in more detail as an example to explain the detection process of an IMS device.

6.2.2.2 Ionization Processes

As $_{28}Ni^{63}$ decays, electrons (e^-) are released to become $_{29}Cu^{63}$ through beta decay:

$$_{28}Ni^{63} \rightarrow _{29}Cu^{63} + e^- \tag{6.3}$$

Electrons released by decay react with molecules in the air to generate positive and negative ions that accumulate in the ionization region to form a pool of ions. The possible types of ions in this pool include $H^+(H_2O)_n$ (n = 1 to 10), NH_4^+, NO^+ as positive ions, and $O_2^-(H_2O)_nX_m$ (X represents a neutral vapor molecule) as the predominant negative ions. Some detectors use additional reactant gas in the ionization region to increase the ionization efficiency of compounds and alter potential interference effects. By transferring associated charges of the ions through different mechanisms such as proton transfer and electron attachment to other molecules, molecules of the targeted chemicals are ionized to form the ions that are detected in the ionization region. An example of proton transfer for the formation of positive ions is

$$M + H^+(H_2O) \rightarrow MH^+ + H_2O \tag{6.4}$$

where M is the molecule of the targeted chemical that reacts with a protonated water molecule to form a positive ion for detection and identification.

There are several ways to form negative ions. Ions can be formed by electron attachment as

$$e^- + M \rightarrow M^- \tag{6.5}$$

Electron transfer is another way that negative ions are formed:

$$O_2^- + M \rightarrow M^- + O_2 \tag{6.6}$$

Negative ions can also be formed through proton abstraction reactions:

$$M + O_2 \rightarrow (M - H)^- + O_2H^+ \tag{6.7}$$

6.2.2.3 Charge Competition

The strength of the radioactive ionization source activity used in a detector is regulated for safety and environmental concerns. Since the number of ions that can be produced in a given unit of time is related to the activity of the ionization source, limiting the activity of the ionization source limits ion production. Consequently, the number of sample molecules in the ionization region, especially at high concentration levels, may exceed ionization capacity. As a result, not all molecules in the ionization region will be equally ionized. The molecules have to compete for charges to become ionized. In the formation of negative ions, molecules with high electron affinity are ionized more easily than those with low electron affinity. Electron affinity is the energy released from an atom when an electron is added. For example, oxygen is a major component of air. Thus, oxygen exists as a background peak in the negative mode. When a sample containing chlorine gas enters the ionization region, the chlorine in the sample competes with oxygen for the negative charges. Because chlorine has a higher electron affinity (2.5 eV) than oxygen (0.45 eV), it is more easily ionized. The response to oxygen therefore becomes smaller as the peak for chlorine appears.

An advantage associated with this charge competition is that it provides an avenue toward the elimination of possible interference from nontargeted compounds in the vapor sample. However, when several compounds with similar charge affinity exist together with the CWA or TIC, they are ionized proportionately to their respective concentrations in the vapor sample. The greater a compound's concentration in the sample, the greater the detector's response. A problem arises when the CWA or TIC has lower charge affinity than interference compounds in the sample, as the interference compounds are more easily ionized than the target compound(s). Relative abundance of interference substances could consume the available ionization energy, affecting the IMS spectrum that in turn may result in false alarms.

6.2.3 Ion Injection Gate

The ions generated in the ionization region are drawn into the drift region by the electric field gradient applied to the drift tube. The generated ions are not allowed to continuously enter the drift region. If the ions continuously enter the drift region, the technique would not be useful. The ions are "injected" into the drift region in a very short pulse controlled by an electronic gate or shutter. Basically, the electronic gate is another electrical field that is vertical to the electric field of the drift tube produced by grids. When set to "open," the field of the shutter is removed and ions enter the drift region. This "open" time is kept as short as possible to achieve good separation of different ions. When the shutter is set to "close," the electric field generated by the shutter prevents additional ions from entering the drift region. This "open-close" process is repeated for each analysis cycle.

Not all ions are injected into the drift tube when the gate is open. The electrical field gradient between the ionization region and ion collector controls the type of ions entering the drift tube. Either positive or negative ions are injected into the drift tube according to the electric field gradient of the drift tube. When the ion collector side has higher voltage than the ionization side (negative mode), negative ions are injected into the drift tube by the electric field. Positive ions enter the tube when the voltage of the collector side is lower than the ionization region (positive mode). Figure 6.2 shows the positive mode. The negative mode works in a similar fashion, except that negative ions rather than positive ions are injected into the drift region by reversing the electric field. The ions that could not enter the drift tube together with the compounds in the vapor that were not ionized are swept out of the detector by the drift flow.

6.2.4 Drift Tube

The drift tube is composed of rings of different voltages to create a homogeneous electric field gradient throughout the entire length of the drift tube. The tube is usually several centimeters long for handheld detectors. Benchtop instruments and some instruments built for research purposes may use a longer drift tube to increase peak resolution capability. Tube diameter can vary from a few millimeters to a few centimeters. The voltage applied to the drift tube is on the order of several hundreds of volts per centimeter. Within the ionization region, both positive and negative ions are generated. The electrical field gradient of the drift tube can be alternated between positive and negative mode to permit detection of both positive and negative ions.

Within the drift tube, a dry airflow called drift flow is used to remove neutralized ions from the collector along with ions that were not injected into the drift tube from the detector. Given that the voltage applied to the drift tube remains constant, the variation of temperature, pressure, and moisture level in the drift flow will significantly affect ion mobility and cause drift time shifts. When the moisture level in the drift flow is high, ion clusters surrounded by water molecules are possible. This reaction changes the shape and size of targeted ions. Consequently, the mobility of ions clustered with the water will differ from the ions without water molecules. Therefore, for reliable detection, it is very important to keep the air supplied to the drift flow dry and free from other organic matter to maintain consistent mobility of the ions of interest.

For instruments without adequate control of the drift tube temperature, change in the ambient temperature becomes an important factor that affects the detection algorithm. Such effects must be compensated for. Fortunately, the effect of this factor can be estimated and compensated for during the signal processes. Alternatively, this effect can be overcome by providing adequate temperature control of the drift tube. Pressure changes also cause a similar effect to that of temperature changes because both temperature and pressure affect density of the gas within the drift tube. The pressure-induced effect can also be estimated and compensated for during signal processing.

6.2.5 Ion Collector and Signal Processor

Various ions collide with the ion collector located at the end of the drift tube at different times due to the separation process that occurs within the tube. These ions release their acquired charges and return to their neutral states. The time interval between when the ions are injected into the drift region and when the ions collide with the collector is recorded as the “drift time.” These drift time data are gathered and used to calculate ion mobility together with correction factors to compensate for temperature and pressure effects. An electric current or voltage is generated and processed by the signal processor into a series of peaks representing the relative drift times for the various substances. The signal strength is proportional to the number of the ions that collided with the collector electrode. Therefore, the amplitude of the peak generated can be used as an indication of relative concentration of the detected chemicals.

Signal processing correlates the relative drift times and signal characteristics of the sample and compares the results to the detector’s internal libraries for pattern matches. If the information generated from the detection signal closely resembles the information stored for a target substance, the detector reports that the substance has been detected and generates an alarm. Because of the limited separation capacity in the short drift tube, the number of targeted compounds programmable for detection must be limited to avoid peak overlapping that leads to detection interference and frequent false alarms.

6.3 TECHNIQUE SPECIFICATION

6.3.1 Detectable Substances

Theoretically, any molecules that can be ionized are detectable by IMS-based detectors. Researchers have shown that IMS detectors can be used in various applications, such as detecting explosives, illicit drugs, CWAs, and many TICs. It has also found other applications. At present, interest is greatest in instruments that can detect multiple chemicals to minimize the number of devices necessary for an operation. This focus has made IMS detectors desirable because of their nonselective but high identification power attributes.

6.3.2 Selectivity

IMS-based detectors are nonselective, they will detect many different vapors, including those that are not of primary interest. Because of the drift tube's ability to separate chemicals, IMS instruments can identify multiple chemicals in the sample. When these detectors are used in the field, sample matrices are not as simple as in the laboratory. Field samples can be quite complex and may contain many different compounds. Unfortunately, many false alarms/identifications can occur because of limitations on resolution. False positive alarms can become problematic when mobility of nontargeted and targeted chemicals is similar. The larger the number of chemicals that the detector can identify, the greater the number of assigned detection peaks. When these peaks are too close together, any substance may have a drift time similar to one of the assigned peaks and a false positive alarm occurs. So, the number of substances included must be limited to minimize the potential of frequent false alarms.

There are several ways to reduce the false positive alarm rate. Adding a gas chromatographic (GC) column in front of the detector may help to reduce the false alarm rate by further increasing the detector's chemical separation power. The additional hardware will result in longer analysis time and more complex instrumentation. Some IMS detectors use chemical additives to reduce false alarms. The addition of a reactant chemical may (1) form a different peak that can be segregated from the peak generated by the target chemical, or (2) suppress the detector response to certain potential interfering chemicals of lower charge affinity, thereby increasing selectivity. Only molecules with charge affinity higher than that of the additives will be ionized and detected.

The idea is that it may be possible to reduce the false positive alarm rate by using more than one peak to identify a target chemical. The probability of two chemicals generating a common peak is much greater than that of the two chemicals generating two or more common peaks at the same time. Therefore, using more than one peak for identification could drastically reduce the false positive alarm rate.

False negative alarms can be an issue when a complex sample matrix is analyzed. As discussed above, molecules with high charge affinity are more easily ionized. If the sample contains chemicals that are ionized more easily than the targeted chemicals, the response to the targeted components may be suppressed. This will result in a false negative response. It is possible to reduce the false negative effects by choosing a reactant additive that could increase the ionization propensity of the targeted chemicals. False negative responses must be addressed. More aggressive research to address this issue is warranted.

6.3.3 Sensitivity and LOD

IMS detectors have reasonable sensitivity for low concentration samples. As shown in Figure 6.3, when concentration in a sample reaches a certain level, these detectors become insensitive to higher concentrations. This is due to the limited supply of ions in the ionization pool, which is insufficient for ionization of all molecules entering the ionization region. In general, the LOD of IMS detectors is

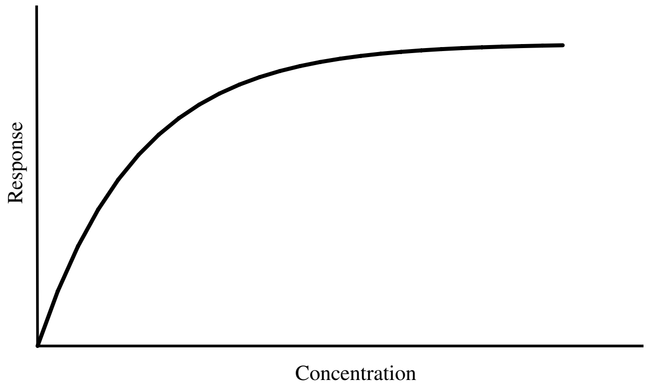

Figure 6.3 IMS response curve.

in the high parts-per-billion to low parts-per-million level, depending on specific chemicals and detector design. IMS detectors tested in the Domestic Preparedness Program showed that the LOD varied from detector to detector, but they are capable of detecting IDLH or JSOR concentration levels.

6.3.4 Response Dynamic Range and Quantitative Capacity

The dynamic response range of an IMS-based detector is less than two to three orders of magnitude, compared to five or six of other detection technologies. The concentration versus response relationship is exponential rather than linear. As discussed earlier, due to the limitation of total available ions in the ionization region, the response may reach its saturation level rather quickly such that a further increase in concentration will not lead to a much stronger signal (Figure 6.3), and thus the relationship is not linear.

However, the estimation of concentration at the low response range based on a linear relationship may be acceptable. For field instruments, the primary objective is to detect whether the sample contains the targeted chemicals. Therefore, the IMS detector's nonlinear relationship between concentration and response is not a great disadvantage for field applications.

6.3.5 Resistance to Environmental Conditions

Temperature, pressure, and humidity may affect the performance of an IMS detector. Potential problems associated with sample contamination may influence detection capability. Dust can be filtered with a particle filter. As discussed above, temperature affects ion mobility. Therefore, variation in environmental temperature affects the detection capability of the instrument. Some detectors operate with a set drift tube temperature. If and when the environmental temperature is higher than the set point, ion mobility changes, resulting in peak position shifts. The shifts can generally be predictable and could be compensated for during signal processing.

Some detectors are equipped with controlled higher tube temperature. The tube temperature can be set much higher than the environmental temperature to avoid shifts in peak positions caused by temperature variance.

Changes in atmospheric pressure will affect ion drift time. This effect has been well studied and can be easily compensated for.

Humidity effects are more complex. The humidity level of the sample cannot be controlled in field environments and may vary from very dry (close to 0% in the desert or in winter) to saturation level (rainy weather). The humidity level affects the species entering the ionization region. Various chemicals can be hydrated to form water clusters and thus different ions. Therefore, peaks observed under high humidity may shift away from the position (mobility) observed at low humidity. When the shift is significant, the detector may fail to identify a targeted chemical. Using a membrane may help to reduce this effect. Testing targeted chemicals at various levels of relative humidity is necessary to fully understand their effects.

A drift flow is used to keep the drift tube clean. It is assumed that there is no chemical reaction occurring in the drift region, and that the ions are in the same form as in the ionization region. When the drift flow is wet, density of the drift flow may change, which causes changes in collision frequency and ion mobility. Wet drift may also react with the ions in the drift tube and change their mobility. Both effects may cause false negative or false positive alarms. Fortunately, the humidity level of the drift flow is controllable through the use of desiccant. Effects can be reduced to a minimum if the humidity level of the drift flow is closely monitored and dried as necessary.

6.3.6 Other Specifications

IMS detectors are mostly designed as direct analysis devices without sample preparation. Response time is seconds if preconcentration and/or GC is not involved. Response time will be contingent on the preconcentration time and/or GC time, if they are used.

Setup time is minimal for a handheld IMS detector. It involves inserting the battery pack for power. Detector warmup may run from a few minutes to half an hour. Most current detectors have internal function and parameters checking procedures installed. This self-test feature verifies that proper operational parameters are satisfied before the unit is ready for use. After the warmup, detector calibration can be easily verified with simulants. If verification is successful, the device is ready to detect.

Handheld IMS detectors can be very small, weighing less than 20 lb, and can operate on batteries. Operation and maintenance of IMS detectors are quite simple, requiring only minimal training. Most detectors are designed to be user-friendly. Minimal or no data interpretation by the operator is required because the microprocessor performs most of the interpretation. The detector will show target substances found in the samples, and will trigger an alarm to alert the operator. The detector can be connected to a computer for more detailed data collection, if necessary.

The most important maintenance effort for IMS detectors is to maintain a dry drift flow. This effort requires routine checking and replacement of dryer cartridges.

6.4 APPLICATIONS

CWA detection using ion mobility technology has been developed for decades. The first CWA detector developed and employed by the U.S. military for field uses, the electrochemical M43® alarm, was replaced by the M43A1® alarm, which is a type of ionization detector. The M43A1 is called the Army Ionization Detector. The initial M43 detector was a wet chemistry type that could detect G-nerve agents and VX, but not HD. The M43 detector requires the use of an oxime solution circulating through an electrochemical cell for detection.

The development of the M43A1 eliminated the need for solution preparation. This device also provided faster and more reproducible responses to less than the IDLH level concentration of nerve agents. The M43A1, however, does not have HD detection capability.

During the mid-1980s, HD detection capability was added to the M43A1 with development of the Mustard Upgrade. Developers experimented with several different techniques, including the use of surface acoustic wave (SAW) sensors and adding negative-mode ionization detection. The effort led to development of a handheld chemical agent monitor called the CAM®. CAM detects the nerve agents in its G-mode or HD in its H-mode, but cannot detect both at the same time. The CAM has undergone several revisions since its inception, as experience gained led to more reliable detection and reducing false detection rates that are inherent to the ionization process. The improved versions include the CAM-2® (Figure 6.4), ICAM®, APD2000®, RAID-M®, IMS-2000®, ACADA-GID3® (Figure 6.5), Sabre2000® (Figure 6.6), and many others. Fact sheets on these devices are included at the end of the chapter, which show that all use IMS technology, but they were designed for different applications.

It is not possible to include discussion of all available detectors in this book. In subsequent chapters, as in the current one, examples are provided for specified technologies. Detectors mentioned in the text and listed in tables are not necessarily better or worse than others; they are presented as examples only.

The Lightweight Chemical Detector, or LCD® series (Figure 6.7), because it was developed more recently, differs slightly from the aforementioned detectors. The LCD uses the open-cell technique that does not contain a radioactive source, and

Figure 6.4 CAM-2 Detector. Photo courtesy of K. Y. Ong.

Figure 6.5 GID-3 Detector. Photo courtesy of K. Y. Ong.

Figure 6.6 Sabre2000 Detector. Photo courtesy of K. Y. Ong.

has eliminated the use of a membrane to protect the drift tube from moisture effects. Elimination of the membrane stemmed from the type of IMS detection used by the M90® detectors developed by Environics Oy of Finland. Environics applied technology similar to the M90, and developed the ChemPro 100®. Both the ChemPro 100 and LCD are currently involved in testing in hopes of replacing or supplementing the Joint Chemical Agent Detector (JCAD) should the current SAW technology fail to deliver.

From the above, it is clear that IMS has been the major technique used for CWA detection for the past 20 years. Until there is a better form of mature detection technology, IMS will continue to rank at the top of the list now and into the near future as the most accepted technology for CWA detection. It is especially true that due to the nonspecific ionization process and identification capability, TIC compounds can easily be detectable using this technique as well. Developing TIC detectors is a top priority for the Department of Homeland Defense in the war against terrorism since the September 11, 2001, incidents.

Figure 6.7 LCD Detector. Photo courtesy of K. Y. Ong.

6.5 FACT SHEETS FOR SELECTED IMS-BASED DETECTORS

Detector Name

ACADA GID-3 Automatic Chemical Agent Detection Alarm, M-22

Manufacturer/Distributor and Contact Information

Smiths Detection
2202 Lakeside Blvd.
Edgewood, MD 21040
Tel: 410-510-9100

Technique Description

This device is a portable CWA detector using IMS.

Chemical Detection Capability and Performance

The ACADA can detect nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. Operable at JSOR temperature extremes. Is type classified by the U.S. as the official CWA detector and alarm that has undergone extensive testing according to the military standards.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds. Consumables include occasional filter and desiccant cartridge replacements. Meets military specifications, and is currently used in the field by the U.S. military.

Detector Name

APD-2000

Manufacturer/Distributor and Contact Information

Smiths Detection
2202 Lakeside Blvd.
Edgewood, MD 21040
Tel: 410-510-9100

Technique Description

This instrument is a handheld CWA and riot control agent detector that uses IMS. It is capable of providing agent identification, and has selectable operating modes including radiation detection capability.

Chemical Detection Capability and Performance

It can detect nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. It can also detect riot control agents such as the pepper spray and mace. Operable at JSOR temperature extremes.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds. Consumables include occasional desiccant cartridge changes. Suitable to serve as a monitor in a CWA or civil defense scenario.

Domestic Preparedness Program Report

Domestic Preparedness Program: Testing of APD2000 Chemical Warfare Agent Detector Against Chemical Warfare Agents Summary Report, August 2000 (www2.sbccom.army.mil/hld/ip/apd2000_detector_download.htm).

Detector Name

CAM/ICAM/CAM-2 Chemical Agent Monitor

Manufacturer/Distributor and Contact Information

Smiths Detection
2202 Lakeside Blvd.
Edgewood, MD 21040
Tel: 410-510-9100

Technique Description

This instrument is a handheld, portable CWA monitoring detector that uses IMS. The CAM-2 has the added detection algorithm for identifying hydrogen cyanide, phosgene, and chlorine, in addition to conventional CWAs.

Chemical Detection Capability and Performance

It can detect nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. Operable at JSOR temperature requirements.

Other Features

Visual bar response indicators. Mode selection required. Can be upgraded to detect new compounds. Consumables include occasional filter and desiccant cartridge changes. Meets military specifications and is currently used in the field by the U.S. military.

Domestic Preparedness Test Report

Domestic Preparedness Program: Testing of the CAM-Chemical Agent Monitor (Type L) Against Chemical Warfare Agents Summary Report, August 2001 (www2.sbccom.army.mil/hld/ip/cam_typel_download.htm).

Detector Name

ChemPro 100 Chemical Warfare Agent Detector

Manufacturer/Distributor and Contact Information

Environics USA
4420 Eastport Parkway
Port Orange, FL 32127
Tel: 386-304-5252

Technique Description

The ChemPro 100 detector is a small, handheld CWA detector that uses Environics' patented "Open Loop Ion Mobility Spectrometry" that can operate IMS without the need for desiccant. The ChemPro 100 uses the Ion Mobility Cell™ for better sensitivity and selectivity.

Chemical Detection Capability and Performance

It detects nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. Operable at JSOR temperature extremes.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds through changeable data libraries. Capable of storing 50 libraries of 60 gas classes each. No consumables except for occasional filter changes. Can be used as a CWA or TIC detector. Has data logging capability and is capable of networking.

Detector Name

IMS 2000 Handheld Chemical Warfare Agent Detector and RAID-M

Manufacturer/Distributor and Contact Information

Bruker Daltonics Inc.
40 Manning Park
Billerica, MA 01821
Tel: 978-663-3600

Technique Description

This detector is a handheld ion mobility spectrometer using ammonia as dopant to permit operation under an ammonia background.

Chemical Detection Capability and Performance

The detector identifies nerve, blister, and blood agents. Sensitivity is expected to meet the current JSOR requirements.

Other Features

Audio and visual alarm indicators. Interface for connecting to computer networks available. Free programmable libraries and software can be downloaded. Back-flush protection to prevent oversaturation.

Detector Name

IPDS Improved Point Detection System

Manufacturer/Distributor and Contact Information

Tradeways Ltd.
184 Duke of Gloucester Street
Annapolis, MD 21401
Tel: 410-295-0821

Technique Description

This device is a shipboard stationary IMS CWA detector that uses elongated ion mobility cells. It is capable of providing superior resolution to counter false alarms. The instrument has algorithm libraries to enable low-level detection of CWAs while filtering out common shipboard types of interference.

Chemical Detection Capability and Performance

It can detect nerve, blister, blood, and choking agents approximately at the JSOR/IDLH concentration levels within 1 min.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds. Operable in a ship environment between 0° to 50°C, and meets military specifications.

Detector Name

Lightweight Chemical Agent Detector (LCD)

Manufacturer/Distributor and Contact Information

Smiths Detection
2202 Lakeside Blvd.
Edgewood, MD 21040
Tel: 410-510-9100

Technique Description

This instrument is a handheld CWA monitoring device using an advanced form of IMS that does not require a radioactive source for ionization. The unit is equipped with an algorithm for detection of hydrogen cyanide, phosgene, and chlorine, in addition to conventional nerve and blister agents.

Chemical Detection Capability and Performance

It can detect nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. The unit includes a detailed user interface that permits identification of detection class and level, as well as data logging and networking.

Other Features

Visual and audio response indicators. Mode selection. Can be upgraded to detect new compounds. Consumables include occasional filter and desiccant cartridge changes.

Detector Name

M-90A1-C Chemical Warfare Agent Detector

Manufacturer/Distributor and Contact Information

Environics USA
4420 Eastport Parkway
Port Orange, FL 32127
Tel: 386-304-5252

Technique Description

This device is a handheld CWA detector using Environics' patented "open loop ion mobility spectrometry" that can operate IMS without the need for desiccant. Unlike conventional IMS detectors, in that M90 the sample does not need to penetrate a membrane before reaching the IMS cell, which makes faster responses possible. It also includes a semiconductor cell for other detection purposes. Chemical identification is based on signal pattern recognition.

Chemical Detection Capability and Performance

It can detect nerve, blister, blood, and choking agents at the JSOR concentration level with near real-time detection. Operable at JSOR temperature extremes.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds through changeable data libraries. No consumables except for occasional filter changes. Meets military specifications and is currently used by the armed forces of many nations. Can be networked and connected to a computer to update libraries and implement other functions without hardware replacements.

Detector Name

RAID-M Handheld Chemical Agent Detector

Manufacturer/Distributor and Contact Information

Bruker Daltonics Inc.
40 Manning Park
Billerica, MA 01821
Tel: 978-663-3600

Technique Description

This detector is a handheld ion mobility spectrometer. It can quickly detect very low concentrations due to highly sophisticated software.

Chemical Detection Capability and Performance

The detector identifies nerve, blister, and blood agents, and some TICs. Sensitivity is expected to meet/exceed current JSOR requirements.

Other Features

Audio and visual alarm indicators. Interface for connecting to computer networks. Additional compound detection can be programmed on request. Automatic purge mode to prevent oversaturation and achieve fast recovery time.

Detector Name

RAID-S® Stationary Rapid Alarm and Identification Device

Manufacturer/Distributor and Contact Information

Bruker Daltonics Inc.
40 Manning Park
Billerica, MA 01821
Tel: 978-663-3600

Technique Description

This device is a stationary ion mobility spectrometer for detecting CWAs and TICs through mode changes. Automatic polarity switching permits detection of all CWAs continuously. Sophisticated software prevents false alarms due to interfering substances. Specially designed for continuous operation for up to 1 year before maintenance.

Chemical Detection Capability and Performance

The detector identifies nerve, blister, and blood agents and some TICs. Sensitivity is expected to meet/exceed current JSOR requirements.

Other Features

Audio and visual alarm indicators. Interface for connecting to computer network. Additional compound detection can be programmed on request. Automatic purge mode to prevent oversaturation and achieve fast recovery time.

Detector Name

Sabre2000

Manufacturer/Distributor and Contact Information

Smiths Detection
2202 Lakeside Blvd.
Edgewood, MD 21040
Tel: 410-510-9100

Technique Description

This instrument is a handheld CWA, TIC, explosive, and narcotics detector that uses IMS. It has selectable operating modes including vapor or particulate sample detection.

Chemical Detection Capability and Performance

The device can detect nerve, blister, blood, and choking agents at JSOR/IDLH concentration levels with near real-time detection. It can also detect many TICs, explosives, and narcotics. It has a surface wiper that can collect persistent compounds for subsequent introduction to the detector for analysis in its particulate detection mode.

Other Features

Audio and visual alarm indicators. Can be upgraded to detect new compounds. Consumables include occasional desiccant cartridge changes. Suitable to serve as a monitor in CWA or Homeland Defense scenarios.

Domestic Preparedness Program Report

Domestic Preparedness Program: Testing of Sabre2000 Handheld Trace and Vapor Detector Against Chemical Warfare Agents Summary Report, August 2001 (www2.sbccom.army.mil/hld/ip/sabre_2000_download.htm).