



# PHOTOIONIZATION DETECTOR (PID) HNU

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## 1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to describe the procedure for using a photoionization detector (PID). The PID is a portable, nonspecific, vapor/gas detector employing the principle of photoionization to detect a variety of chemical compounds, both organic and inorganic, in air. This procedure is applicable to the HNU PI-101, HNU ISPI-101, and HW-101 used for air monitoring.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

## 2.0 METHOD SUMMARY

The PID is a useful general survey instrument at hazardous waste sites. A PID is capable of detecting and measuring real-time concentrations of many organic and inorganic vapors in air. A PID is similar to a flame ionization detector (FID) in application; however, the PID has somewhat broader capabilities in that it can detect certain inorganic vapors. Conversely, the PID is unable to respond to certain low molecular weight hydrocarbons, such as methane and ethane, that are readily detected by FID instruments.

The PID employs the principle of photoionization. The analyzer will respond to most vapors that have an ionization potential less than or equal to that supplied by the ionization source, which is an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to

release an electron and form a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The sensor is housed in a probe and consists of a sealed ultraviolet light source that emits photons with an energy level high enough to ionize many trace organics, but not enough to ionize the major components of air (e.g., nitrogen, oxygen, carbon dioxide). The ionization chamber exposed to the light source contains a pair of electrodes, one a bias electrode, and the second the collector electrode. When a positive potential is applied to the bias electrode, an electro-magnetic field is created in the chamber. Ions formed by the adsorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter, directly, in units above background. Several probes are available for the PID, each having a different eV lamp and a different ionization potential. The selection of the appropriate probe is essential in obtaining useful field results. Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture.

Three probes, each containing a different UV light source, are available for use with the HNU. Energies are 9.5, 10.2, and 11.7 eV. All three detect many aromatic and large molecular hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe.

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials higher than that of the lamp will not be detected. Ionization potentials for various atoms, molecules, and compounds are given in

Table 1 (Appendix A). The ionization potential of the major components of air, oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to about 15.6 eV and are not ionized by any of the three lamps.

Table 2 (Appendix A) illustrates ionization sensitivities for a large number of individual species when exposed to photons from a 10.2 eV lamp. Applications of each probe are included in Table 3 (Appendix A).

While the primary use of the HNU is as a quantitative instrument, it can also be used to detect certain contaminants, or at least to narrow the range of possibilities. Noting instrument response to a contaminant source with different probes can eliminate some contaminants from consideration. For instance, a compound's ionization potential may be such that the 9.5 eV probe produces no response, but the 10.2 eV and 11.7 eV probes do elicit a response.

### **3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE**

This section is not applicable to this SOP.

### **4.0 INTERFERENCES AND POTENTIAL PROBLEMS**

#### **4.1 PID Instrument Limitations**

1. The PID is a nonspecific total vapor detector. It cannot be used to identify unknown substances; it can only roughly quantify them.
2. The PID must be calibrated to a specific compound.
3. The PID does not respond to certain low molecular weight hydrocarbons, such as methane and ethane. In addition, the HNU does not detect a compound if the probe has a lower energy than the compound's ionization potential.
4. Certain toxic gases and vapors, such as carbon tetrachloride and hydrogen cyanide, have high ionization potentials and cannot be detected with a PID.

5. Certain models of PID instruments are not intrinsically safe. The HNU PI-101 and HW-101 are not designed for use in potentially flammable or combustible atmospheres. Therefore, these models should be used in conjunction with a Combustible Gas Indicator. The ISPI-101 is intrinsically safe, however.
6. Electrical power lines or power transformers may cause interference with the instrument and thus cause measurement errors. Static voltage sources such as power lines, radio transmissions, or transformers may also interfere with measurements.
7. High winds and high humidity will affect measurement readings. The HNU may become unusable under foggy or humid conditions. An indication of this is the needle dropping below zero, or a slow constant climb on the read-out dial.
8. The lamp window must be periodically cleaned to ensure ionization of the new compounds by the probe (i.e., new air contaminants).
9. The HNU measures concentrations from about 1-2000 ppm, although the response is not linear over this entire range. For example, if calibrated to benzene, the response is linear from about 0-600 units above background. This means the HNU reads a true concentration of benzene only between 0 and 600. Greater concentrations are detected at a lower level than the true value.
10. This instrument is not to be exposed to precipitation (rain). The units are not designed for this service.
11. Do not use this instrument for head space analysis where liquids can inadvertently be drawn into the probe.

#### **4.2 Regulatory Limitations**

Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods

Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

## 5.0 EQUIPMENT/APPARATUS

The following equipment is required for PID operation:

- C PID (HNU)
- C Operating manual
- C Probes: 9.5 eV, 10.2 eV, or 11.7 eV
- C Battery charger for PID
- C Spare batteries
- C Jeweler's screwdriver for adjustments
- C Tygon tubing
- C NBS traceable calibration gas
- C "T" valve for calibration
- C Field Data Sheets/Site Logbook
- C Intake assembly extension
- C Strap for carrying PID
- C Teflon tubing for downhole measurements
- C Plastic bags for protecting the PID from moisture and dirt

Note: Battery charge status - This instrument may be kept on continuous charge without battery damage.

## 6.0 REAGENTS

- C Isobutylene standards for calibration
- C Benzene reference standard
- C Methanol for cleaning ionization chamber (GC grade)
- C Mild soap solution for cleaning unit surfaces
- C Specific gas standards when calibrating to a specific compound
- C Light source cleaning compound Cat. No. PA101534-A1 (For use only with 9.5 and 10.2 lamps)

The HNU is calibrated in accordance with the operations manual using isobutylene as the calibration standard. The operations manual may also be referred to for alternate calibration to a specific compound.

## 7.0 PROCEDURES

### 7.1 Preparation

Check out and ensure the proper operation of the PID, as appropriate, using the equipment checklist provided in Sections 5.0 and 6.0 and the steps listed below.

### 7.2 Start-Up Procedures

1. Allow the temperature of the unit to equilibrate to its surrounding. This should take about five minutes.
2. Attach the probe to the read-out unit. Match the alignment key, then twist the connector clockwise until a distinct locking is felt. Make sure the microswitch (red button) is depressed by the locking ring.
3. Turn the FUNCTION switch to the battery check position. Check to ensure that the indicator reads within or beyond the green battery arc on the scale plate. If the indicator is below the green arc, or if the red LED comes on, the battery must be charged prior to using.
4. To zero the instrument, turn the FUNCTION switch to the STANDBY position and rotate the ZERO POTENTIOMETER until the meter reads zero. Wait 15-20 seconds to ensure that the zero adjustment is stable; if not, then readjust.
5. Check to see that the SPAN POTENTIOMETER is set at the appropriate setting for the probe being used (i.e., 9.8 for the 10.2 eV probe, 5.0 for the 11.7 eV probe, 1 for the 9.5 eV probe. Note: The setting may vary based on the intensity of the light source).
6. Set the FUNCTION switch to the desired range (i.e., 0-20, 0-200, 0-2000).
7. Listen for the fan operation to verify fan function.

8. Look for ultraviolet light source in the probe to verify function. Do not look at light source from closer than six inches with unprotected eyes, observe only briefly.
9. Check instrument with an organic point source, such as a magic marker, prior to survey to verify instrument function.
10. Routinely during the day, verify the useful battery life by turning the function switch to BATT and schedule the instrument's use accordingly.

### **7.3 Field Operation**

#### **7.3.1 Field Calibration**

1. Follow the start-up procedure in Section 7.2.
2. Set the FUNCTION switch to the range setting which includes the concentration of the calibration gas.
3. Attach a regulator to a disposable cylinder of calibration gas. Connect the regulator to the probe of the HNU with a piece of clean tygon tubing. Open the valve on the regulator.
4. After 15 seconds, the meter reading should equal the response value as indicated on the calibration gas cylinder used. If the reading is within  $\pm 15\%$  of the response value, then the instrument can be field calibrated to the response value using the external SPAN ADJUSTMENT control. The SPAN ADJUSTMENT control should be adjusted to a lower setting until the correct reading has been obtained. The lower the number on the SPAN ADJUSTMENT control, the greater the instrument sensitivity. If the SPAN ADJUSTMENT control has to be adjusted below a setting of 4.00, the unit should be red-tagged and returned for repairs.
5. If the meter reading is greater than  $\pm 15\%$  of the response value of the calibration gas used, then the instrument should be red-tagged and returned for re-calibration.

6. Record the following information in the site logbook: the instrument ID number (U.S. EPA decal or serial number if the instrument is a rental), the initial and final span settings, the date and time, concentration and type of calibration gas used, and the name of the person who field calibrated the instrument.
7. If the PID does not start up, check out, or calibrate properly, the instrument should not be used. Under no circumstances is work requiring air monitoring with a PID to be done without a proper functioning instrument.
8. In some field applications, with the exception of the probe's inlet and exhaust, the PID should be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation.

#### **7.3.2 Operation**

1. All readings are to be recorded in the site logbook. Readings should be recorded, following background readings, as "units above background," not ppm.
2. As with any field instrument, accurate results depend on the operator being completely familiar with the operator's manual. The instructions in the operating manual should be followed explicitly in order to obtain accurate results.
3. Position the probe assembly close to the area to be monitored because the low sampling rate allows for only very localized readings. Under no circumstances should the probe tip assembly be immersed in fluid.
4. While taking care to prevent the PID from being exposed to excessive moisture, dirt, or contamination, monitor the work activity as specified in the site Health and Safety Plan. The PID survey should be conducted at a slow to moderate rate of speed and the intake assembly (the probe) slowly swept from side to side. There is a three to five second delay in read-out depending upon the instruments sensitivity to the contaminant.

5. During drilling activities, PID monitoring is performed at regular intervals downhole, at the headspace, and in the breathing zone. In addition, where elevated organic vapor levels are encountered, monitoring may be performed in the breathing zone during actual drilling. When the activity being monitored is other than drilling, readings should emphasize breathing zone conditions.
6. When the activity is completed or at the end of the day, carefully clean the outside of the PID with a damp disposable towel to remove any visible dirt.

## 7.4 Post Operation

1. Turn FUNCTION Switch to OFF.
2. Return the PID to a secure area and check the calibration (Section 7.3.1.) before charging. Connect the instrument to charger and plug in the charger. The probe must be connected to the readout unit to charge the HNU.
3. Complete logbook entries, verifying the accuracy of entries and signing/initialing all pages. Following completion of a series of "0" readings, verify the instrument is working as in Section 7.3.1.
4. Check the equipment, repair or replace damaged equipment, and charge the batteries.

## 7.5 Equipment Calibration

1. Follow the start-up procedure in Section 7.2.
2. Set the FUNCTION switch to the range setting which includes the concentration of the calibration gas.
3. Attach a regulator to a cylinder of calibration gas. Connect the regulator to the probe of the NHU with a piece of clean tygon tubing. Open the valve on the regulator.
4. After 15 seconds, the meter reading should equal the response value as indicated on the calibration gas cylinder used. If the reading is greater than  $\pm 15\%$  of the actual

concentration, an internal calibration is necessary. Unlock the SPAN POTENTIOMETER dial before adjusting it. Adjust the SPAN POTENTIOMETER to the span setting recommended for the probe being used (i.e., 9.8 for the 10.2 eV probe, 5.0 for the 11.7 eV probe, 1 for the 9.5 eV probe). To calibrate the instrument, unscrew the bottom support screw and lift the instrument out of the case. Locate and adjust the trimpot "R-32" (near the top of the printed circuit board) by inserting a small screwdriver and gently turning. When the instrument gives the correct reading for the calibration gas being used, reassemble it.

5. Record the following information in the calibration logbook: the instrument identification number (U.S. EPA barcode number or serial number if the instrument is a rental), the initial and final span settings, the date and time, concentration and type of calibration gas used, and the name of the person who calibrated the instrument. Affix a sticker to the instrument indicating the person who performed the calibration, the date of calibration, and the due date of the next calibration.
6. Turn the FUNCTION switch to OFF and connect the instrument to the charger. The probe must be connected to the readout unit to ensure that the unit accepts a charge.

## 8.0 CALCULATIONS

The HNU is a direct reading instrument. Readings are interpreted as units above background rather than ppm.

## 9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.
2. All instrumentation must be operated in

accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

## **10.0 DATA VALIDATION**

This section is not applicable to this SOP.

## **11.0 HEALTH AND SAFETY**

When working with potentially hazardous materials, follow U.S. EPA, OSHA, or corporate health and safety practices.

The HNU is certified by OSHA standards for use in Class 1, Division 2, Groups A, B, C, and D locations.

## **12.0 REFERENCES**

HNU Systems, Inc. 1975. "Instruction Manual for Model PI-101 Photoionization Analyzer."

U.S. Code of Federal Regulations, 49 CFR Parts 100 to 177, Transportation, revised November 1, 1985.

U.S. Environmental Protection Agency. 1984. "Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods, Second Edition", EPA-600/4-84-076, Environmental Monitoring Systems Laboratory, Office of Research and Development, Las Vegas, Nevada.

International Air Transport Association Dangerous Goods Regulations

# APPENDIX A

## Tables

TABLE 1. Ionization Potentials

<u>SOME ATOMS AND SIMPLE MOLECULES</u>				<u>PARAFFINS AND CYCLOPARAFFINS</u>	
Molecule	IP(Ev)	Molecule	IP (eV)	Molecule	IP (eV)
H	13.595	I <sub>2</sub>	9.28	Methane	12.98
C	11.264	HF	15.77	Ethane	11.65
N	14.54	HCl	12.74	Propane	11.07
O	13.614	HBr	11.62	n-Butane	10.63
Si	8.149	HI	10.38	I-Butane	10.57
S	10.357	SO <sub>2</sub>	12.34	n-Pentane	10.35
F	17.42	CO <sub>2</sub>	13.79	ii-Pentane	10.32
Cl	13.01	COS	11.18	2,2-Dimethylpropane	10.35
Br	11.84	CS <sub>2</sub>	10.08	n-Hexane	10.18
I	10.48	N <sub>2</sub> O	12.90	2-Methylpentane	10.12
H <sub>2</sub>	15.426	NO <sub>2</sub>	9.78	3-Methylpentane	10.08
N <sub>2</sub>	15.580	O <sub>3</sub>	12.80	2,2-Dimethylbutane	10.06
O <sub>2</sub>	12.075	H <sub>2</sub> O	12.59	2,3-Dimethylbutane	10.02
CO	14.01	H <sub>2</sub> S	10.46	n-Heptane	10.08
CN	15.13	H <sub>2</sub> Se	9.88	2,2,4-Trimethylpentane	9.86
NO	9.25	H <sub>2</sub> Te	9.14	Cyclopropane	10.06
CH	11.1	HCN	13.91	Cyclopentane	10.53
OH	13.18	C <sub>2</sub> N <sub>2</sub>	13.8	Cyclohexane	9.88
F <sub>2</sub>	15.7	NH <sub>3</sub>	10.15	Methylcyclohexane	9.85
Cl <sub>2</sub>	11.48	CH <sub>3</sub>	9.840		
Br <sub>2</sub>	10.55	CH <sub>4</sub>	12.98		

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

#### ALKYL HALIDES

Molecule	IP (eV)	Molecule	IP (eV)
HCl	12.74	1-bromo-2-methylpropane	10.09
Cl <sub>2</sub>	11.48	2-bromo-2-methylpropane	9.89
CH <sub>4</sub>	12.98	1-bromopentane	10.10
Methyl chloride	11.28	HI	10.38
Dichloromethane	11.35	I <sub>2</sub>	9.28
Trichloromethane	11.42	Methyl iodide	9.54
Tetrachloromethane	11.47	Diiodomethane	9.34
Ethyl chloride	10.98	Ethyl iodide	9.33
1,2-Dichloroethane	11.12	1-iodopropane	9.26
1,3-Dichloropropane	10.85	2-iodopropane	9.17
1-chlorobutane	10.67	1-iodobutane	9.21
2-chlorobutane	10.65	2-iodobutane	9.09
1-chloro-2-methylpropane	10.66	1-iodo-2-methylpropane	9.18
2-chloro-2-methylpropane	10.61	2-iodo-2-methylpropane	9.02
HBr	11.62	1-iodopentane	9.19
Br <sub>2</sub>	10.55	F <sub>2</sub>	15.7
Methyl bromide	10.53	HF	15.77
Dibromomethane	10.49	CFCl <sub>3</sub> (Freon 11)	11.77
Tribromomethane	10.51	CF <sub>2</sub> Cl <sub>2</sub> (Freon 12)	12.31
CH <sub>2</sub> BrCl	10.77	CF <sub>3</sub> Cl (Freon 13)	12.91
CHBr <sub>2</sub> Cl	10.59	CHClF <sub>2</sub> (Freon 22)	12.45
Ethyl bromide	10.29	CF <sub>2</sub> Br <sub>2</sub>	11.67
1,1-dibromoethane	10.19	CH <sub>3</sub> CF <sub>2</sub> Cl (Genetron 101)	11.98
1-bromo-2-chloroethane	10.63	CFCl <sub>2</sub> CF <sub>2</sub> Cl	11.99
1-bromopropane	10.18	CF <sub>3</sub> CCl <sub>3</sub> (Freon 113)	11.78
2-bromopropane	10.075	CFHBrCH <sub>2</sub> Br	10.75
1,3-dibromopropane	10.07	CF <sub>2</sub> BrCH <sub>2</sub> Br	10.83
1-bromobutane	10.13	CF <sub>3</sub> CH <sub>2</sub> I	10.00
2-bromobutane	9.98	n-C <sub>3</sub> F <sub>7</sub> I	10.36
1-chloropropane	10.82	n-C <sub>3</sub> F <sub>7</sub> CH <sub>2</sub> Cl	11.84
2-chloropropane	10.78	n-C <sub>3</sub> F <sub>7</sub> CH <sub>2</sub> I	9.96
1,2-dichloropropane	10.87	CF <sub>2</sub> Br <sub>2</sub>	11.07

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

<u>ALIPHATIC ALCOHOL, ETHER, THIOL, AND SULFIDES</u>		<u>ALIPHATIC ALDEHYDES AND KETONES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Water	12.59	Carbon Dioxide	13.79
Methyl alcohol	10.85	Formaldehyde	10.87
Ethyl alcohol	10.48	Acetaldehyde	10.21
n-propyl alcohol	10.20	Propionaldehyde	9.98
i-propyl alcohol	10.16	n-butyraldehyde	9.86
n-butyl alcohol	10.04	Isobutyraldehyde	9.74
Dimethyl ether	10.00	n-valeraldehyde	9.82
Diethyl ether	9.53	Isovaleraldehyde	9.71
n-propyl ether	9.27	Acrolein	10.10
i-propyl ether	9.20	Crotonaldehyde	9.73
Hydrogen Sulfide	10.46	Benzaldehyde	9.53
Methanethiol	9.440	Acetone	9.69
Ethanethiol	9.285	Methyl ethyl ketone	9.53
1-propanethiol	9.195	Methyl n-propyl ketone	9.39
1-butanethiol	9.14	Methyl i-propyl ketone	9.32
Dimethyl sulfide	8.685	Diethyl ketone	9.32
Ethyl methyl sulfide	8.55	Methyl n-butyl ketone	9.34
Diethyl sulfide	8.430	Methyl i-butyl ketone	9.30
di-n-propyl sulfide	8.30	3,3-dimethyl butanone	9.17
		2-heptanone	9.33
		Cyclopentanone	9.26
		Cyclohexanone	9.14
		2,3-butanedione	9.23
		2,4-pentanedione	8.87

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

<u>ALIPHATIC ACIDS AND ESTERS</u>		<u>ALIPHATIC AMINES AND AMIDES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Carbon Dioxide	13.79	Ammonia	10.15
Formic acid	11.05	Methyl amine	8.97
Acetic acid	10.37	Ethyl amine	8.86
Propionic acid	10.24	n-propyl amine	8.78
n-butyric acid	10.16	i-propyl amine	8.72
Isobutyric acid	10.02	n-butyl amine	8.71
n-valeric acid	10.12	i-butyl amine	8.70
Methyl formate	10.815	s-butyl amine	8.70
Ethyl formate	10.61	t-butyl amine	8.64
n-propyl formate	10.54	Dimethyl amine	8.24
n-butyl formate	10.50	Diethyl amine	8.01
Isobutyl formate	10.46	Di-n-propyl amine	7.84
Methyl acetate	10.27	Di-i-propyl amine	7.73
Ethyl acetate	10.11	Di-n-butyl amine	7.69
n-propyl acetate	10.04	Trimethyl amine	7.82
Isopropyl acetate	9.99	Triethyl amine	7.50
n-butyl acetate	10.01	Tri-n-propyl amine	7.23
Isobutyl acetate	9.97	Formamide	10.25
Sec-butyl acetate	9.91	Acetamide	9.77
Methyl propionate	10.15	N-methyl acetamide	8.90
Ethyl propionate	10.00	N,N-dimethyl formamide	9.12
Methyl n-butyrate	10.07	N,N-dimethyl acetamide	8.81
Methyl isobutyrate	9.98	N,N-diethyl formamide	8.89
		N,N-diethyl acetamide	8.60

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

<u>OTHER ALIPHATIC MOLECULES WITH N ATOM</u>		<u>OLEFINS, CYCLO-OLEFINS, ACETYLENES</u>	
Molecule	IP (eV)	Molecule	IP (eV)
Nitromethane	11.08	Ethylene	10.515
Nitroethane	10.88	Propylene	9.73
1-nitropropane	10.81	1-butene	9.58
2-nitropropane	10.71	2-methylpropene	9.23
HCN	13.91	Trans-2-butene	9.13
Acetonitrile	12.22	Cis-2-butene	9.13
Propionitrile	11.84	1-pentene	9.50
n-butyronitrile	11.67	2-methyl-1-butene	9.12
Acrylonitrile	10.91	3-methyl-1-butene	9.51
3-butene-nitrile	10.39	3-methyl-2-butene	8.67
Ethyl nitrate	11.22	1-hexene	9.46
Methyl thiocyanate	10.065	1,3-butadiene	9.07
Ethyl thiocyanate	9.89	Isoprene	8.845
Methyl isothiocyanate	9.25	Cyclopentene	9.01
Ethyl isothiocyanate	9.14	Cyclohexene	8.945
		4-methylcyclohexene	8.91
		4-cinylcyclohexene	8.93
		Cyclo-octatetraene	7.99
		Acetylene	11.41
		Propyne	10.36
		1-butyne	10.18

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

#### SOME DERIVATIVES OF OLEFINS

Molecule	IP (eV)
Vinyl chloride	9.995
Cis-dichloroethylene	9.65
Trans-dichloroethylene	9.66
Trichloroethylene	9.45
Tetrachloroethylene	9.32
Vinyl bromide	9.80
1,2-dibromoethylene	9.45
tribromoethylene	9.27
3-chloropropene	10.04
2,3-dichloropropene	9.82
1-bromopropene	9.30
3-bromopropene	9.7
CF <sub>3</sub> CCl=CClCF <sub>3</sub>	10.36
n-C <sub>5</sub> F <sub>11</sub> CF=CF <sub>2</sub>	10.48
Acrolein	10.10
Crotonaldehyde	9.73
Mesityl oxide	9.08
Vinyl methyl ether	8.93
Allyl alcohol	9.67
Vinyl acetate	9.19

#### HETEROCYCLIC MOLECULES

Molecule	IP (eV)
Furan	8.89
2-methyl furan	8.39
2-furaldehyde	9.21
Tetrahydrofuran	9.54
Dihydropyran	8.34
Tetrahydropyran	9.26
Thiophene	8.860
2-chlorothiophene	8.68
2-bromothiophene	8.63
Pyrrole	8.20
Pyridine	9.32
2-picoline	9.02
3-picoline	9.04
4-picoline	9.04
2,3-lutidine	8.85
2,4-lutidine	8.85
2,6-lutidine	8.85
Tribromoethylene	9.27

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

#### AROMATIC COMPOUNDS

Molecule	IP (eV)	Molecule	IP (eV)
Benzene	9.245	Phenyl isothiocyanate	8.520
Toluene	8.82	Benzonitrile	9.705
Ethyl benzene	3.76	Nitrobenzene	9.92
n-propyl benzene	8.72	Aniline	7.70
i-propyl benzene	8.69	Fluoro-benzene	9.195
n-butyl benzene	8.69	Chloro-benzene	9.07
s-butyl benzene	8.68	Bromo-benzene	8.98
t-butyl benzene	8.68	Iodo-benzene	8.73
o-xylene	8.56	o-dichlorobenzene	9.07
m-xylene	8.56	m-dichlorobenzene	9.12
p-xylene	8.445	p-dichlorobenzene	8.94
Mesitylene	8.40	1-chloro-2-fluorobenzene	9.155
Durene	8.025	1-chloro-3-fluorobenzene	9.21
Styrene	8.47	1-bromo-4-fluorobenzene	8.99
o-methyl styrene	8.35	o-fluorotoluene	8.915
Ethynylbenzene	8.815	m-fluorotoluene	8.915
Napthalene	8.12	p-fluorotoluene	8.785
1-methylnapthalene	7.69	o-chlorotoluene	8.83
2-methylnapthalene	7.955	m-chlorotoluene	8.83
Biphenyl	8.27	p-chlorotoluene	8.70
Phenol	8.50	o-bromotoluene	8.79
Anisole	8.22	m-bromotoluene	8.81
Phenetole	8.13	p-bromotoluene	8.67
Benzaldehyde	9.53	o-iodotoluene	8.62
Acetophenone	9.27	m-iodotoluene	8.61
Benzenethiol	8.33	p-iodotoluene	8.50
Phenyl isocyanate	8.77	Benzotrifluoride	9.68
		o-fluorophenol	8.66

## APPENDIX A (Cont'd)

### Tables

TABLE 1. Ionization Potentials (Continued)

#### MISCELLANEOUS MOLECULES

Molecule	IP (eV)
Ethylene oxide	10.565
Propylene oxide	10.22
p-dioxane	9.13
Dimethoxymethane	10.00
Diethoxymethane	9.70
1,1-dimethoxyethane	9.65
Propiolactone	9.70
Methyl disulfide	8.46
Ethyl disulfide	8.27
Diethyl sulfite	9.68
Thiolacetic acid	10.00
Acetyl chloride	11.02
Acetyl bromide	10.55
cyclo-C <sub>6</sub> H <sub>11</sub> CF <sub>3</sub>	10.46
(n-C <sub>3</sub> F <sub>7</sub> )(CH <sub>3</sub> )C=O	10.58
Trichlorovinylsilane	10.79
(C <sub>2</sub> F <sub>5</sub> ) <sub>3</sub> N	11.7
Isoprene	9.08
Phosgene	11.77

## APPENDIX A (Cont'd)

### Tables

TABLE 2. Relative Photoionization Sensitivities for Gases

Chemical	Relative Sensitivity	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Acid	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Acrolein, Propylene, Cyclohexanone, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C5-C7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	
Paraffin (C1-C4)	0	Methane, Ethane

NOTE: Relative sensitivity = meter reading when measuring 10 ppm of the listed gas with instrument with 10.2 eV probe calibrated for 10 ppm of benzene, span pot setting = 9.8 for direct reading of benzene.

## APPENDIX A (Cont'd)

### Tables

TABLE 3. Typical Applications of Interchangeable Probes

	Ionization Potentials	Relative Sensitivity	
p-Xylene	8.44	0.10	0.104
p-Chlorotoluene	8.70	0.09	0.112
Toluene	8.82	0.09	0.112
o-Chlorotoluene	8.83	0.075	0.112
Ethyl Acetate	9.19	0.075	0.112
Benzene	9.24	0.10	0.10
Methyl Mercaptan	9.24	0.10	0.072
Pyridine	9.32	0.075	0.122
Allyl Alcohol	9.67	0.10	0.111
Crotonaldehyde	9.88	0.075	0.104
Amyl Alcohol	9.80	0.09	0.116
Cyclohexane	9.88	0.075	0.104
Vinyl Chloride	9.95	0.085	0.112
Butanol	10.94	0.09	0.176
Ammonia	10.15	0.06	0.160
Acetic Acid	10.37	0.04	0.560
Ethylene	10.52	0.0	0.320
Ethylene Oxide	10.56	0.0	0.298

$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$