

**AMERICAN VACUUM SOCIETY STANDARD (tentative)
AVS 2.3—1972**

**Procedure for Calibrating Gas Analyzers of
the Mass Spectrometer Type**

Foreword

This Foreword is not a part of AVS 2.3—1972.

This publication specifies practices tentatively approved as standard by the American Vacuum Society for the calibration of gas analyzers of the mass spectrometer type and is one of a series published by the American Vacuum Society. It contains data secured from many sources and represents the best thinking of a number of experts in the field. After several years of use this standard will be forwarded to the American National Standards Institute with the request that it be used as a basis for a USA Standard. Suggestions for improvement gained in use of this standard will be welcome. They should be sent to the American Vacuum Society, 335 East 45 Street, New York, New York 10017. The AVS Committees which drafted and approved this standard had the following personnel at the time of approval.

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1. Scope

This standard is concerned with calibration procedures for determining the minimum detectable partial pressure (MDPP) of gas analyzers of the mass spectrometer type. Procedures are also given for evaluating the resolution of the analyzer. (It is to be noted that, in general, MDPP and resolution are not independent characteristics. See Sec. 5.) In connection with the determination of MDPP, consideration is also given to discrimination (see definition 3.10).

In measuring MDPP, it is necessary to observe the pressure of the (neon) gas being used for the measurement (see 3.19). In the present procedure, this pressure is set in the neighborhood of 1×10^{-8} Torr to avoid difficulties that may be present in making measurements of lower pressures. However, nothing in this standard is to be understood to preclude the use of a lower pressure for determining MDPP. The changes in the procedure necessitated by the use of such a lower pressure are slight, and will be obvious.

2. Introduction

2.1. Mass Spectrometers. A mass spectrometer consists of a mass spectrometer tube, associated electronic and electric circuits and controls, and various output indicating devices, such as meters, recorders, etc. The gas to be studied in the mass spectrometer is, in part,

ionized, usually by impact of electrons from a hot filament. Each chemical species in the gas produces (positive) ions which are unique in kind and/or amount. A study of the kind and quantity of ions formed in the spectrometer can, therefore, yield a quantitative analysis of the gas being examined. (It is to be noted that a given molecular species may produce more than one kind of ion; molecules generally yield a "cracking pattern.")

The analysis is carried out by varying the adjustment of the scanning parameter (see definitions) of the mass spectrometer tube. In principle, for each value of the scanning parameter, only ions of a single mass/charge ratio are electrically detected. The magnitude of the electric current due to these ions is determined and is a measure of the concentration of the molecule or atom that produced the ions.

2.2. Spectrometer Facilities. It will be assumed in this standard that the mass spectrometer undergoing test has the following facilities:

- (a) An attenuator for reducing the output indication to at least 1/1000 of its unattenuated value (an attenuation factor of 1000) for analyzers capable of detecting a minimum partial pressure not less than 10^{-11} Torr, and to at least 1/10⁶. (an attenuation factor of 10⁶) for analyzers capable of detecting a minimum partial pressure of 10^{-12} , 10^{-13} , or 10^{-14} Torr.
- (b) A means for varying the scanning parameter (see definitions) at a constant or a smoothly varying rate.

2.3. Scans. A scan (see definitions) is usually shown as a trace on a recorder chart; the abscissa is time, mass, voltage, gauss, etc., and the ordinate is assumed proportional to ion current or "output." See Fig. 1. It can also be shown as a table of values, an oscilloscope trace, etc. (The term "mass spectrum" is synonymous with scan or mass scan.) In this standard, it will be assumed for sake of simplicity that the scan is a recorder trace (see Sec. 7.4 "Recorder"), and that the recorder displacements are proportional to input currents.

2.4. Assumptions of Mass Spectrometry. In the inter-

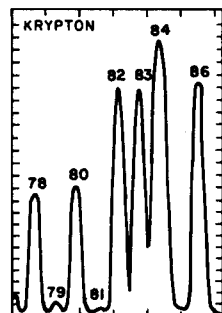


FIGURE 1. A mass scan of krypton, showing isotopic masses 78—84 and 86.

pretation of mass spectra, the following assumptions are usually made:

- (1) Each molecular species gives a constant mass spectrum, or cracking pattern, characteristic of the molecule.
- (2) The spectrum of a mixture is the same as that obtained by the linear superposition of individual spectra, account being taken of gas pressures.
- (3) The ion current which corresponds to a particular peak (see definitions) is proportional to the partial pressure (see definitions) of that component, in a gas sample, which is responsible for the peak. While ion current is proportional to partial pressure, the proportionality constant differs, in general, from gas to gas.

(Note: The range of pressure for which ion current is proportional to partial pressure is limited for a given spectrometer and differs among spectrometers).

These assumptions are not strictly correct. [See A. J. B. Robertson, *Mass Spectrometry*, Methuen & Co., Ltd., London (1954), p. 87.] However, for the purpose of this standard, the assumptions are acceptable as stated.

3. Definitions

3.1. Reference. The definitions in this section will be those of the *Glossary of Terms Used in Vacuum Technology*, issued by the Committee on Standards, American Vacuum Society, where they are suitable. Other definitions have been formulated specifically for this standard.

3.2. Scan (noun). Mass Scan. *Mass Spectrum*—Any kind of display which shows the kinds and relative amounts of the ions produced from the gas in a given mass spectrometer.

3.3 Peak (noun)

(a) In a graphical spectrum, that part of the trace which exhibits a maximum of ion current output. See the peaks or roughly triangular excursions in Fig. 1.

(b) By extension, a maximum of ion current output in any type of scan.

3.3.1 Mass Peak. Same as "Peak." A peak is due to ions of a certain mass/charge ratio and is therefore referred to, for instance, as the "mass 28 peak."

3.4. Cracking Pattern. The characteristic pattern (i.e., kinds and relative amounts) of ions produced by a given gas in a given mass spectrometer under given conditions. The term derives from the fact that molecules are decomposed or "cracked" in the mass spectrometer tube to produce a characteristic set of atomic or molecular fragments.

3.5. Scanning Parameter. That characteristic of the electric and/or magnetic field(s) (voltage, frequency, gauss, etc.) in a mass spectrometer tube whose value is varied so as to vary the mass/charge ratio of the ions which will be detected.

3.6. Scan (verb). The act or process of varying the scanning parameter(s) so as to produce a scan covering all or part of the mass range of the mass spectrometer.

3.7 Peak (verb). To so adjust one or more of the operating parameters of a mass spectrometer tube as to maximize output current due to an ion of specified mass/charge ratio.

3.8. Mass Number. The whole number nearest the ionic (atomic or molecular) mass expressed in either atomic mass units or as (chemical) atomic or molecular weight. For instance, the atomic mass of one of the isotopes of neon is approximately 19.9987 atomic mass units and its mass number is 20. (The foregoing assumes singly-charged ions.) Expressed otherwise, the mass number is the sum of the number of protons and the number of neutrons in the nucleus.

3.9. Mass Range. The range of mass numbers throughout which a given analyzer can be used for obtaining significant analyses; the mass range is characterized by the mass numbers of the lightest and heaviest singly charged ions which can be detected.

3.10. Discrimination. The property of a gas analyzer of giving different output indications for the same pressure of different gases. In the present standard, the overall discrimination is measured; that is, the various sources of discrimination are not individually determined. In particular, the discrimination as measured includes the effects of ionization cross section.

3.11. Peak Width, W . In a graphical spectrum, the length of the base of a peak, the base being defined by the intersection or tangency of the legs of the peak with a reference base line. The specification of such a reference line is an important function of this standard. In some discussions, the symbol Δm or ΔM is used for peak width rather than W .¹ The units of W are atomic mass units; in some cases, a conversion of units may be necessary (see 2.3 and 4.1).

3.12. Zero Output Base Line. In principle, a line on a graphical scan which represents the mass spectrometer output when no ions are being detected. In practice, a line drawn tangent to the base of fully resolved peaks, that is, peaks due to ionic masses sufficiently different from masses of neighboring peaks so that the ion current due to the peaks is not affected by that of their neighbors.

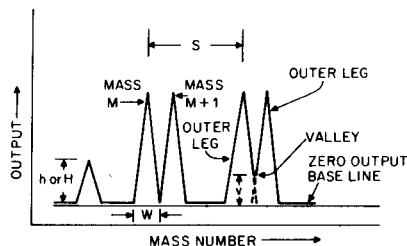


FIGURE 2. Idealized peaks in a graphical scan.

3.13. Peak Separation, S . The distance parallel to the abscissa between the apex of two peaks, distance being measured in the same units as W (sec 2.3 and 4.1).

3.14 Peak Height, H or h . The distance from the zero output base line to the apex of a given peak. Units of height are arbitrary.

3.15. Valley. This term refers to two immediately adjacent peaks. It is the rise, if any, above the zero output base line, exhibited by the trace between the two peaks. The height of the valley is the distance from the base line to the lowest point in the valley. See " v " on the right side of Fig. 2. The height of the valley is to be measured in the same units as the peak height.

3.16. Resolution

3.16.1. General Definition. The ability, or a measure of the ability, of a mass spectrometer to separate the peaks produced by ions of different mass/charge ratios.

3.16.2. Absolute Resolution. (See General Definition above.) A measure of the ion-separating ability of a mass spectrometer, at a given mass M , given by the peak width, W , at M :

$$\text{Absolute resolution (at } M) = W \text{ amu.}$$

3.16.3. Unity Resolution Mass(es). The mass number(s) at which the absolute resolution is one (amu) or "unity."

3.16.4. Resolving Power. At a given mass M , the ratio of M to peak width W :

$$\text{resolving power} = \frac{M}{W} = \frac{M}{\Delta M} \text{ (see 3.11).}$$

3.17 Mole Fraction. The ratio of the number of atoms (or molecules) of a given constituent of a mixture to the total number of atoms (or molecules) in the mixture. For *ideal* gases, the mole fraction has the same value as the fraction based on volume; in general, vacuum analyzers are used in the pressure range where gases have been ideally.

3.18. Partial Pressure. In a mixture of gases, the partial pressure of a constituent is the product of the total pres-

sure of the mixture and the mole fraction of the given constituent.

3.19. Sensitivity Terms

3.19.1 Sensitivity. The change in response of any device divided by the change in input which caused the response. For a mass analyzer, the sensitivity is, thus, the change in current output, divided by the change in partial pressure of the gas causing the change. As pointed out in 2.4-(3), the sensitivity may be constant over only a range of operating pressures. Mass spectrometers may, nevertheless, be useful outside this pressure range, and the procedures of this standard are applicable at all working pressures.

The units of sensitivity are usually amperes per Torr. Since the scale of output indicating devices is not always calibrated in units of current, in this standard sensitivity will be calculated in scale divisions, or in percent of full scale, per Torr.

3.19.2. Minimum Detectable Partial Pressure (MDPP). For a mass analyzer, the *minimum* partial pressure of a *specific* gas in a gas sample, which, when the gas is analyzed, produces an output equal to the noise (see below); i.e., the signal-to-noise ratio equals one. This means that, if the peak-to-peak noise is N (scale divisions, amperes, etc.) then the total peak-to-peak output (signal due to specified gas plus noise) is $2N$ (see Fig. 6).

For the purposes of this standard, the specific gas referred to in the preceding paragraph shall be the neon isotope of mass 21.²

In theory, the MDPP is equal to the noise multiplied by the reciprocal of sensitivity as defined in 3.19.1, noise being expressed in the same units as output.

According to Sec. 2.4 (2), the assumption is made that the presence in the spectrometer of other gas than the specific gas involved in determining MDPP has no effect on the determination. In some practical circumstances this may not be completely correct. (See "Scope" with reference to pressure at which MDPP is determined.)

3.19.3. Nitrogen Sensitivity. The MDPP multiplied by the ratio of sensitivity for neon to sensitivity for nitrogen.

3.20. Noise. The relatively rapid changes in the zero output base line due to spurious output indications.

3.21. Attenuation Factor. That factor by which an (attenuated) output indication must be multiplied to obtain the equivalent *unattenuated* output indication. An unattenuated indication corresponds to an attenuation factor of 1.

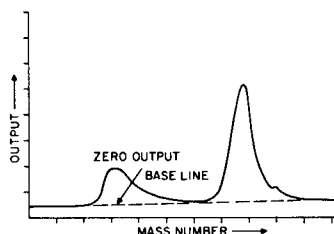


FIGURE 3. Asymptotic approach to base line.

4. Discussion of Resolution

4.1. Mass Scale. Some mass spectrometers produce a graphical scan having an abscissa which is not linear in mass number. It then becomes necessary, for the calculation of resolution, to convert the abscissa to a linear mass scale. To do this, it is assumed that, for a *sufficiently small* range of mass numbers, the abscissa is actually *linear* in mass number. To convert from the abscissa scale to mass units, the following formula is used:

$$L = \frac{S'}{|M_1 - M_2|} = \frac{S'}{\Delta M},$$

where

S' = peak separation in any convenient units (centimeters, volts, cycles per sec, etc.),

L = the number of units, of the kind chosen for S' , equivalent to 1 mass unit,

M_1 = mass of peak at which resolution is to be determined,

M_2 = mass of a neighboring peak,

$\Delta M = M_1 - M_2$.

Then, if W' is the peak width in the same units as those of S' ,

$$\begin{aligned} \text{absolute resolution} &= \frac{W'}{L} \quad (\text{by definition}) \\ &= \Delta M \times \frac{W'}{S'}. \end{aligned} \quad (1)$$

4.2. Reference Base Line. The ideal triangular peaks of Fig. 2 present no difficulty to the measurement of W or W' , the peak width, which determines resolution. Actual peaks, as represented in Fig. 3, approach the zero output base line in a more or less asymptotic fashion; the precise point of contact is therefore difficult to determine. For this and other reasons, a reference base line, parallel to and above the zero output base line, is used for determining peak width in connection with resolution. The peak(s) used for determining resolution are required to have certain geometrical relationships to the reference base line. Moreover, since resolution is generally a function of mass number, ΔM of Eq. (1) 4.1, must be restricted. A full discussion of the restrictions on peak shape when Eq. (1) is used is given in Appendix C.

4.2.1. Peak Width. For the purposes of the definition of absolute resolution in 3.16.2, the peak width shall be measured along a reference base line drawn above and

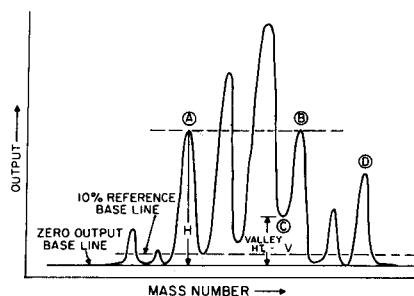


FIGURE 4. Restrictions on valley height.

parallel to the zero output base line, the distance above the latter being 10% of the height of the peak at which resolution is being determined.

4.2.2. Valley Height. See Fig. 4. For greatest ease of measurement of peak width, the 10% reference base line should intersect both peak legs as shown at the peak marked D. However, in this standard it will be required that the 10% reference base line intersect one of the legs of a peak at which resolution is to be determined; it must then either intersect or be tangent to the other leg as at peak A. In other words, valley height, v , at one leg (that intersected by the 10% reference base line) shall be less than 10% of peak height, H , and at the other leg shall not exceed 10% of H . The peak B meets the first requirement, but fails to meet the second requirement at the valley marked C. Peak B does not permit of a determination of resolution in the sense of this standard.

4.3. Peak Width. The peak width, W , to be used in the calculation of absolute resolution, shall be measured along the reference base line and between its points of intersection or tangency with the legs of the peak at which resolution is being determined.

5. Sensitivity vs Resolution

To a greater or lesser extent, depending on the type of gas analyzer concerned, sensitivity and resolution are interrelated. That is to say, resolution may be improved by decreasing sensitivity and vice versa. It is, therefore, essential to know the resolution that obtains when a given sensitivity has been achieved, or the sensitivity that obtains when a given resolution has been achieved. Accordingly, one provision of this standard is that the *coexisting* resolution and sensitivity of a gas analyzer *always* be stated as a single specification.

This interrelation of sensitivity and resolution must be considered in any procedure for determining these quantities, and such consideration has been given in this standard. See Secs. 11, 12, and 14.

6. Outline of Methods

6.1. Sensitivity. The gas analyzer to be tested is attached to the chamber (see Fig. 5) of a vacuum system. The system is pumped to its ultimate pressure.

Nitrogen gas is introduced into the system to a specified pressure and the adjustments of the analyzer tube set according to the manufacturer's directions so as to maximize the response of the tube to nitrogen, or otherwise optimize performance. In subsequent operations, *all* controls and adjustments of the gas analyzer, with the exception of the scanning parameter control and attenuator, are to remain fixed.

After removal of the nitrogen, neon gas is introduced into the system to a specified pressure and the system gas scanned so as to yield a record of the peaks due to masses 18–25. From the height of the mass 20 peak of the neon isotopes and the total neon pressure, the sensitivity for neon 20 can be calculated. From the height of the mass 21 peak, the MDPP can be calculated, due account being taken of noise and background. From the relative heights of neon and nitrogen peaks, the nitrogen (partial pressure) sensitivity, MDP (N_2), can be calculated.

6.2. Discrimination. The neon gas is replaced by krypton and xenon in turn, and the (partial pressure) sensitivity determined for each.

6.3. Resolution. The test setup is the same as that used in 6.1 for sensitivity. After the system has reached its ultimate pressure, neon gas is introduced into the system to a specified pressure. The gas analyzer is caused to scan the system gas so as to record the peaks due to ions of masses 18–25.

The record is examined in light of 3.16.2 and the discussion in 4, and Appendix C, to determine the absolute resolution at mass 20. For this purpose, the peak(s) due to neon of isotopic mass 20 (and 22) are used.

The procedure used for neon is repeated with krypton, singly and doubly ionized, and with xenon, to obtain the absolute resolution at mass-to-charge ratios of 86, 43, and 136.

The four resolution figures so obtained are plotted against mass number. A smooth curve is passed through the four points. In the case of analyzers whose absolute resolution is largely independent of mass, the curve yielded by the four resolution values may approximate a straight line parallel to the mass axis. In other cases, the masses for which the absolute resolution is 2, 1 and $\frac{1}{2}$ amu are picked off the curve; these values will constitute an approximate statement of the dependence of resolution on mass-to-charge ratio.

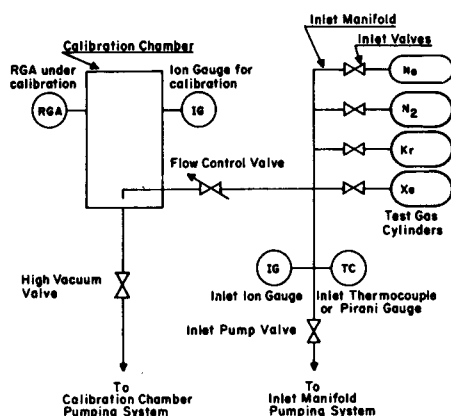


FIGURE 5. Test system.

7. Apparatus

7.1. Block Diagram of System. Refer to Fig. 5. Note: If 10^{-3} Torr sensitivity is available on TC or Pirani on inlet, inlet IG is not needed. TC or Pirani is desirable to conserve inlet gas for expensive types.

7.2. Vacuum System. It is recommended that the system be made of metal. It shall contain a test chamber as shown in Fig. 5. The test chamber shall contain ports for the gas analyzer under test and an ionization gauge tube; these ports shall be in the same horizontal plane.

The calibration chamber pumping system should be of such type and material that it is capable of evacuating the calibration chamber (with gas analyzer and ionization gauge filaments in operation) to a total pressure equal to or lower than that specified for sensitivity measurement by the analyzer manufacturer.

The inlet manifold vacuum system should be capable of evacuating the inlet manifold to significantly less than 10^{-3} Torr.

7.2.1. Pressure Gauge Tube and Control. The gauge tube shall be located so as to insure that no interaction occurs between the gauge tube and the analyzer. Isolation of the tube and analyzer may require the introduction of properly placed electrically conducting shields in the vacuum system.

It will be assumed that the gauge tube and control have been calibrated to read nitrogen gas pressure directly. The correction factor for neon, relative to nitrogen, should be known for the gauge tube. The correction factor is the factor by which the output indication produced by pure neon has to be multiplied in order to yield true neon pressure. If the neon correction factor is not known, it shall be taken to be 4. This is an average value and assumes an electron bombardment energy between 70 and 150 eV.

The term "indicated pressure" is used in this standard as an equivalent for gauge output reading; for gases

other than nitrogen the indicated pressure is not true pressure:

indicated pressure = gauge reading

$$= \text{true pressure} \times \frac{1}{\text{correction (gauge) factor}}$$

Indicated pressure is the same as "equivalent nitrogen pressure."

7.2.2. Gas Flow System. The vacuum system specified in 7.2 shall have attached to it one or more gas supply lines. The line(s) shall be attached to the high vacuum side of the vacuum system and at a point (or points) between the pump and the points of attachment of the analyzer and the gauge tube. The lines shall lead to a source(s) of gas(es). These gases, as specified in 6.1 and 6.2, are neon, nitrogen, krypton, and xenon. Interposed between the source(s) of gas and the vacuum system shall be a shut-off valve (or shut-off valves) and a flow control valve. The flow control valve should be capable of controlling the flow of the mentioned gases into the vacuum system, from a pressure greater than 1 Torr, so as to attain the specified pressure in the vacuum system. Preferably, in order to minimize outgassing, the flow control valve should be of all-metal construction. Means shall be provided for exhausting the manifold between the gas inlet valve(s) and the flow control valve. The flow control valve should maintain constant flow over a 1-h period. In this way if the pumping speed remains constant the system pressure will also remain constant.

7.3. Gases. The following four gases are required; neon, nitrogen, krypton, and xenon. These shall be of a purity exceeding 99%.

7.4. Recorder. This standard requires that the output of the gas analyzer being tested be graphically presented by means of a chart recorder. The recorder shall be an instrument which traces a continuous line and which has a time constant (63%) not greater than one second. The recorder shall be so buffered that there is no interaction between the recorder and the meter or other output-indicating device of the gas analyzer; i.e., so that the velocity of response of neither generates sufficient electrical signal to affect the indication of the other. If the recorder is connected in parallel with the output indicator, this interaction will be negligible if each has an input resistance 1000 times that of their common voltage source, or if the recorder draws 1/1000 as much current as the indicator.

While some recorders have automatic decade-switching capabilities, it will be assumed that this recorder can cover only a single linear range; it is also assumed that recorder displacement is proportional to the input current. In those cases where the analyzer has an output meter, controls shall be available which permit adjusting the zero of the recorder to the zero of the meter, and

full-scale deflection of the recorder to full-scale deflection of the meter. This is necessary to permit direct correlation of meter and recorder indications and also to prevent possible injury to one or the other of these devices. However, in order to prevent complications in the language of this standard, it will be assumed that the recorder is the only output indicating device, and that controls for adjusting zero indication and for attenuating output indication act directly on the recorder.

8. Test Procedure—Minimum Detectable Partial Pressure

8.1. Preliminary

8.1.1. Attach the analyzer tube under test to the chamber of the system defined in Fig. 5.

8.1.2. Close flow control valve and start the pumping systems.

8.1.3. Evacuate the calibration chamber. Turn on ionization gauge and analyzer filaments when the pressure is within their specified ranges. Continue evacuation to the pressure specified for sensitivity measurement by the analyzer manufacturer, using bakeout if required.

Evacuate inlet manifold to a pressure significantly less than 10^{-3} Torr, then close the inlet pump valve.

8.1.4. Connect recorder to analyzer output.

8.1.5. Be sure that the chamber ion gauge has been thoroughly degassed and indicates the pressure in the chamber, acting as neither a significant gas source or gas sink.

8.2. Sensitivity for Nitrogen

8.2.1. Be certain that the flow control valve is closed.

8.2.2. Pressurize the inlet manifold with nitrogen to at least 1 Torr.

8.2.3. Note the ion gauge indication of chamber pressure.

8.2.4. Turn off the analyzer tube filament.

8.2.5. Set the attenuator to the full sensitivity setting (attenuation factor of 1).

8.2.6. Set the zero control so that the recorder pen indicates between 2% and 5% of full scale.

8.2.7. Turn on the analyzer tube filament.

8.2.8. Record the spectrum in the region encompassing mass 28 using as small an attenuation factor as is necessary to obtain peaks in this range, if possible.

8.2.9. Open the flow control valve sufficiently to give a change in chamber ion gauge reading of *approximately* 1×10^{-8} Torr over the value obtained in 8.2.3.

8.2.10. Again record the spectrum in the mass 28 region, using the change in peak heights from those recorded in 8.2.8 as a means of verifying the identity of mass 28.

If no nitrogen peak is obtained with attenuation factor of 1, it will be necessary to further increase the nitrogen pressure.

If the mass 28 peak is off scale, set the attenuator so as to obtain on-scale deflections for mass 28.

8.2.11. Scan the nitrogen (mass 28) peak.

8.2.12. Set all analyzer controls as indicated by the manufacturer, so as to maximize the nitrogen peak height, or as otherwise specified to optimize analyzer performance; see Sec. 14, particularly the 2nd paragraph.

8.2.13. Adjust the attenuator and/or the gas flow so that the mass 28 peak height is between 10% and 20% of full scale on the recorder.

8.2.14. Note the height of the peak in per cent of full scale, being certain to note also the setting of the attenuator.

8.2.15. Note the pressure indicated by the chamber ion gauge.

8.2.16. Increase the flow of nitrogen by means of the flow control valve, so that the recorder chart deflection becomes approximately full scale.

8.2.17. Note the height of the peak in percent of full scale.

8.2.18. Note the pressure indicated by the chamber ion gauge.

8.2.19. Subtract the % full-scale height noted in 8.2.14 from that noted in 8.2.17. Call the difference the nitrogen deflection. Subtract the pressure noted in 8.2.15 from that noted in 8.2.18. Call the difference the pressure difference.

8.2.20. The sensitivity for nitrogen, in full-scale deflections, with attenuation factor of 1, per unit of pressure is calculated from the formula

sensitivity for N_2

$$= \frac{\text{nitrogen deflection} \times \text{attenuation factor}}{100 \times \text{pressure difference}}$$

(full scale deflections per unit pressure).

8.2.21. Close the flow control valve.

8.3. Sensitivity for Neon

8.3.1 With all controls and adjustments as they were at the end of 8.2.21, remove nitrogen from inlet system by opening the inlet pump valve. When the pressure is significantly less than 10^{-3} Torr, close the inlet pump valve.

8.3.2. If indicated pressures greater than 10^{-7} Torr were used in the previous procedure, take such steps as may be necessary to insure that the ion gauge is in pressure equilibrium with the chamber.

8.3.3. Allow the system to pump back to its previous (8.1.3) pressure.

8.3.4. Pressurize the inlet manifold with neon to at least 1 Torr.

8.3.5. Note the ion gauge indication of chamber pressure.

8.3.6. Turn off the analyzer tube filament.

8.3.7. Set the attenuator for attenuation factor of 1.

8.3.8. Set the zero control so that the recorder pen indicated between 2% and 5% of full scale.

8.3.9. Turn on the analyzer tube filament.

8.3.10. Record the spectrum in the region encompassing mass 20 using as small an attenuation factor as is necessary to obtain peaks in this range, if possible.

8.3.11. Open the flow control valve enough to give a change in chamber ion gauge reading of *approximately* 1×10^{-8} Torr over the value obtained in 8.3.5.

8.3.12. Again record the spectrum in the mass 20 region, using the change in peak heights from 8.3.10 as a means of verifying the identity of mass 20.

If no neon peak is obtained, it will be necessary to further increase the indicated pressure.

If the mass 20 peak is off scale, set the attenuator so as to obtain on-scale deflections for mass 20.

8.3.13. Scan the neon (mass 20) peak.

8.3.14. Adjust the attenuator and/or the gas flow so that the mass 20 peak height is between 10% and 20% of full scale on the recorder.

8.3.15. Note the height of the peak in per cent of full scale, being certain to note also the setting of the attenuator.

8.3.16. Note the pressure indicated by the chamber ion gauge.

8.3.17. Increase the flow of neon by means of the flow control valve, so that the recorder deflection becomes approximately full scale.

8.3.18. Note the height of the peak in percent of full scale.

8.3.19. Note the pressure indicated by the chamber ion gauge.

8.3.20. Subtract the % full-scale height recorded in 8.3.15 from that recorded in 8.3.18. Call the difference the Neon Deflection. Subtract the pressure recorded in 8.3.16 from that recorded in 8.3.19. Call the difference the pressure difference.

8.3.21. The sensitivity for neon in full-scale deflections on full sensitivity setting, per unit of pressure is calculated from the formula

sensitivity for neon

$$\frac{\text{neon deflection} \times \text{attenuation factor}}{4 \times 0.905 \times 100 \times \text{pressure difference}}$$

(full scale deflections per unit pressure).

In this calculation, the ionization gauge factor for neon relative to nitrogen has been taken as 4. The partial pressure of neon isotope mass 20 in the neon gas source³ has been taken to be 90.5% of the total neon pressure.

8.4. Minimum Detectable Partial Pressure (Neon).

Note: If the Resolution of the analyzer under test is numerically greater than 1 amu at mass 20, the following procedure may not be applicable.

8.4.1. With indicated pressure and all adjustments as they were at the end of 8.3.21, alter the scan control, manually, to a position as close as can be judged to the center of the mass 21 peak.

8.4.2. (a) If the attenuator is set for an attenuation factor of 100 or for any greater attenuation, set it for 100 times less attenuation, e.g., if the attenuation factor is 1000, set for attenuation factor of 10.

(b) If the attenuator is set for an attenuation factor of 10, set it for an attenuation factor of 1 and increase the flow of neon so that the pressure is approximately 10 times that noted in 8.3.19.

(c) If the attenuator is set for an attenuation factor of 1, increase the flow of neon so that the pressure is 100 times that noted in 8.3.19 or is the maximum specified for operation of the analyzer, whichever is lower.

8.4.3. Scan the neon mass 21 peak. The peak height should be approximately 25% of full scale.

8.4.4. Adjust the scan control so that recorder output is at the valley between the mass 21 and the mass 22 peaks.

8.4.5. If the output shows excursions below the *zero line* of the recorder chart, adjust the zero control so that such excursions extend only to the zero line. See Fig. 6.

8.4.6. Again scan the neon mass 21 peak and note the height of the peak above the *zero line* of the recorder chart in percent of full scale. Note the indicated pressure, P_{Ne} , and the attenuator setting.

8.4.7. Again adjust the scan control to the valley between the mass 21 and the mass 22 peaks.

8.4.8. If the attenuator is not set for attenuation factor of 1, set it at this setting.

8.4.9. Close the flow control valve and allow the system to attain its ultimate pressure. Bakeout is not necessary at this point.

8.4.10. Record the analyzer output for 5 min.

8.4.11. For each one minute interval of the recorded output trace draw a straight line approximation. For each of these five segments of the trace, determine the maximum (absolute) deviation of the trace from the straight line approximation, in percent of full scale. The average of these deviations, multiplied by 2, is the Noise, N , in percent of full scale.

Note: (1) In determining noise, any large deviation occurring not more than once, in the length of the 5 min recording, is to be neglected. (2) In Section 7.4, it is specified that the recorder have a time constant not greater than 1 sec. If the recorder being used has a time constant substantially smaller than 1 sec, the noise figure may be larger than would be obtained with a 1 sec recorder.

(3) The above determination may not be applicable to analyzers which have very low noise, that is, time intervals between noise pulses which are so long as to require count rate measurements.

8.4.12. Set the attenuator to the value used in 8.4.2 (and 8.4.6.) and scan the neon mass 21 peak.

Record the height of the peak, in percent of full scale, from the chart zero line. Subtract this height from the peak height recorded in 8.4.6. Call the remainder $H(21)$.

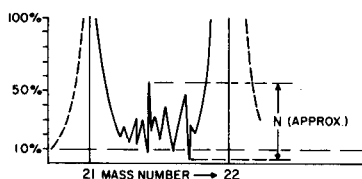


FIGURE 6. Noise determination.

8.4.13. Observe and record the indicated pressure on the chamber ion gauge. Call this pressure P_0 .

8.4.14. The MDPP of neon 21, is that which gives a peak height equal to the peak-to-peak noise. This is calculated from the formula:

$$\text{MDPP} = (P_{Ne} - P_0) \times 4 \times 0.00265 \times \frac{N}{H(21) \times \text{attenuation factor}}$$

In this formula, P_{Ne} is the pressure reading of the chamber ion gauge in step 8.3.19. P_0 is the pressure reading of the chamber ion gauge in step 8.4.13. 4 is the gauge factor used to convert the indicated reading of the ion gauge, calibrated for nitrogen, to true neon pressure. (See, however, 7.21.) 0.00265 is the fractional abundance of Ne^{21} in natural neon. N is the percent full scale noise (peak-to-peak) measured in step 8.4.11. $H(21)$ is the percent full scale neon peak height determined in step 8.4.12.

8.5. Sensitivity for Krypton and Xenon.

8.5.1. The procedures and calculations of section 8.3.1 to 8.3.21 are repeated, the neon being replaced in turn by krypton and xenon, and the peaks being measured at masses 86 and 136, respectively. The formulas to be used are

sensitivity for krypton

$$= \frac{\text{krypton deflection} \times \text{attenuation factor}}{0.52 \times 0.173 \times \text{pressure difference} \times 100}$$

sensitivity for xenon

$$= \frac{\text{xenon deflection} \times \text{attenuation factor}}{0.35 \times 0.089 \times \text{pressure difference} \times 100}$$

In these calculations, the ionization gauge factors for krypton and xenon relative to nitrogen have been taken as 0.52 and 0.35, respectively.⁴ The partial pressure of krypton isotope mass 86 has been taken as 17.3% of the total krypton pressure and that of the xenon isotope mass 136 has been taken as 8.9% of the total xenon pressure.⁵

9. Minimum Detectable Pressure of Nitrogen

9.1. Nitrogen Minimum Detectable Pressure. [MDP (N_2)] shall be calculated as follows:

$$\text{MDP}(N_2) = \text{MDPP}(\text{Ne}) \times \frac{\text{sensitivity for neon}}{\text{sensitivity for nitrogen}}$$

10. Test Procedure—Resolution

10.1. Preliminaries

10.1.1. Nonlinear scales. In light of the discussion in 4.1, it will be necessary, for some gas analyzers, to observe two neighboring peaks in the graphical scan (see Appendix C) in order to calculate a mass scale. The procedure which follows will cover such cases. Where the scan has an abscissa which is linear in mass, the same procedure may be followed leaving out certain indicated steps.

10.1.2. Test setup. Prepare the test assembly as in 8.1. Adjust the analyzer tube for maximum nitrogen sensitivity (see, however, Secs. 8.2.12 and 14) following the procedure of 8.2.1–8.2.12, then close the flow control valve.

10.2. Resolution at Mass 20

10.2.1. Attach a source of neon gas to the gas-monitoring system, if such a source is not already present. Perform steps 8.1.3–8.2.11 using neon instead of nitrogen and setting the scanning control so that the peak due to neon mass 20 appears on the recorder chart.

10.2.2. Set the attenuator for an attenuation factor of 100, if it is not already so set. If the mass 20 peak is greater than full scale, reduce the flow of neon by means of the flow control valve so that the peak is on scale and greater than 75% of full scale. If the mass 20 peak is less than 75% of full scale, increase the flow of neon until the peak is larger than 75% of full scale.

10.2.3. Scan so that the spectrum is recorded for the masses between, approximately, 18 and 25. The peak(s) due to neon mass 20 (and neon mass 22) will be used for determining resolution.

Note: If the resolution of the analyzer at mass 20 is numerically greater than 2 amu, the neon peak(s) may not be suitable for determining resolution. See 4.2.2 and, for the use of other gases than neon, Sec. 11.

10.2.4. Measure the height of the mass 20 peak as a percent of full scale, above the zero output base line determined by the scan. Call this height $h(20)$.

10.2.5. Calculate 10% of $h(20)$ and draw a reference base line on the recorder chart at this height above the zero output base line and parallel to it. The line is to be drawn along the entire length of the scan. In accordance with 4.2.2, the reference base line should intersect the outer leg of the mass 20 peak and at least be tangent to the other leg. (The outer leg is that one on the low mass number side of the peak.)

10.2.6. (a) For analyzers having a linear mass scale, measure the distance in amu between the point of intersection of the reference base line with the outer leg of the mass 20 peak and the point of intersection or tangency

with the other leg. Call this distance $W(20)$, the peak width.

(b) For analyzers not having a linear mass scale, measure the distance referred to in (a) above, in any convenient units. Call the distance $W'(20)$.

10.2.7. For analyzers not having a linear mass scale, measure the distance, in the units of $W'(20)$, and parallel to the abscissa between the apex of the mass 20 peak and the apex of the mass 22 peak. Call this distance $S'(20)$, the peak separation.

10.2.8. (a) For analyzers having a linear mass scale, the absolute resolution at mass 20, is determined (see definition 3.16.2) as

$$\text{absolute resolution} = W(20) \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

(b) For analyzers not having a linear mass scale, the absolute resolution at mass 20 shall be calculated from the formula [see 4.1, Eq. (1)].

$$\text{absolute resolution} = 2 \times \frac{W'(20)}{S'(20)} \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

10.3. Resolution at Mass 86

10.3.1. Repeat 10.1.2 if necessary.

10.3.2. Repeat 10.2.1, using krypton instead of neon and setting the scanning control so that the peak due to krypton mass 86 appears on the recorder chart.

10.3.3. As in 10.2.2, set the attenuator for an attenuation factor of 100 and adjust the monitoring valve so that the peak due to mass 84 has a height between 75 and 100% of full scale.

10.3.4. Scan so that the spectrum is recorded for the masses between, approximately, 75 and 90. The peak(s) due to krypton mass 86 (and krypton mass 84) will be used for determining resolution. Note: If the Absolute Resolution of the analyzer at mass 86 is numerically greater than 2 amu, the krypton peak(s) may not be suitable for determining resolution. See 4.2.2 and, for the use of other gases than krypton, Sec. 11.

10.3.5. Measure the height of the mass 86 peak as a percent full scale above the zero output base line determined by the scan. Call this height $h(86)$.

10.3.6. Calculate 10% of $h(86)$ and draw a reference base line on the recorder chart at this height above the zero output line and parallel to it. The line is to be drawn along the entire length of the scan. In accordance with

4.2.2, the reference base line should intersect the outer (high mass side) leg of the mass 86 peak and at least be tangent to the other leg.

10.3.7. Measure the peak width, $W(86)$ or $W'(86)$ of the mass 86 peak as was done for neon 20 in 10.2.6 (a) or 10.2.6 (b).

10.3.8. For analyzers not having a linear mass scale, measure the peak separation $S'(86)$ for the peaks of mass 86 and 84, as was done for neon in 10.2.7.

10.3.9. (a) For analyzers having a linear mass scale, the absolute resolution at mass 86 is determined (see Definition 3.16.2) as

$$\text{absolute resolution} = W(86) \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

(b) For analyzers not having a linear mass scale, the absolute resolution at mass 86 shall be calculated from the formula

$$\text{absolute resolution} = 2 \times \frac{W'(86)}{S'(86)} \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

10.4. Resolution at Mass 43

10.4.1. With conditions as they were at the end of step 10.3.3, scan so that the spectrum is recorded for the masses between, approximately, 35 and 45. The peak(s) due to (doubly charged) krypton of mass-to-charge ratio 43 (and krypton of mass-to-charge ratio 42) will be used for determining resolution.

Notes: (1) Care must be taken to differentiate the mass 43 peak from the mass 44 peak which is generally present and due to CO_2 .

(2) If the absolute resolution of the analyzer at mass 43 is numerically greater than 1 amu, krypton peaks may not be suitable for determining resolution. See 4.2.2 and, for the use of gases other than krypton, Sec. 11.

10.4.2. If the mass 42 peak is less than 75% of full scale, increase the flow of krypton by means of the flow control valve until the peak is larger than 75% of full scale and less than full scale.

10.4.3. Measure the height of the mass 43 peak as a percent of full scale above the zero output base line determined by the scan. Call this height $h(43)$.

10.4.4. Calculate 10% of $h(43)$ and draw a reference base line at this height above the zero output base line and parallel to it. The line is to be drawn along the entire length of the scan.

10.4.5. Measure the peak width, $W(43)$ or $W'(43)$ of the mass 43 peak as was done for neon 20 in 10.2.6 (a) or 10.2.6 (b).

10.4.6. For analyzers not having a linear mass scale, measure the peak separation $S'(43)$ for the peaks of mass 43 and 42, as was done for neon in 10.2.7.

10.4.7. (a) For analyzers having a linear mass scale, the absolute resolution at mass 43 will be determined (see definition 3.16.2) as

$$\text{absolute resolution} = W(43) \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

(b) For analyzers not having a linear mass scale, the absolute resolution at mass 43 shall be calculated from the formula

$$\text{absolute resolution} = 1 \times \frac{W'(43)}{S'(43)} \text{ amu,}$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

10.5. Resolution at Mass 136

10.5.1. Repeat 10.1.2 if necessary.

10.5.2. Repeat 10.2.1 using xenon instead of neon and setting the scanning control so that the peak due to xenon mass 136 appears on the recorder chart.

10.5.3. As in 10.2.2, set the attenuator to an attenuation factor of 100 and adjust the monitoring valve so that the peak due to mass 134 has a height between 50 and 100% of full scale.

10.5.4. Scan so that the spectrum is recorded for the masses between, approximately, 125 and 140. The peak(s) due to xenon mass 136 (and xenon mass 134) will be used for determining resolution. Note: If the absolute resolution of the analyzer at mass 136 is numerically greater than 2 amu, the xenon peak(s) will not be suitable for determining resolution. See 4.2.2 and, for the use of other gases than xenon, Sec. 11.

10.5.5. Measure the height of the mass 136 peak as a percent of full scale above the zero output base line determined by the scan. Call this height $h(136)$.

10.5.6. Calculate 10% of $h(136)$ and draw a reference base line on the recorder chart at this height above the zero output base line and parallel to it. The line is to be drawn along the entire length of the scan. In accordance with 4.2.2, the reference base line should intersect the outer (high mass side) leg of the mass 136 peak and at least be tangent to the other leg.

10.5.7. Measure the peak width $W(136)$ or $W'(136)$ of the mass 136 peak as was done for neon 20 in 10.2.6 (a) or 10.2.6 (b).

10.5.8. For analyzers not having a linear mass scale, measure the peak separation $S'(136)$ for peaks of mass 136 and 134, as was done for neon in 10.2.7.

10.5.9. (a) For analyzers having a linear mass scale, the absolute resolution is determined (see definition 3.16.2) as

$$\text{absolute resolution} = W(136)\text{amu},$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

(b) For analyzers not having a linear mass scale, the absolute resolution at mass 136 shall be calculated from the formula

$$\text{absolute resolution} = 2 \times \frac{W'(136)}{S'(136)} \text{ amu},$$

with

$$\text{MDP}(N_2) = A \times 10^{-B} \text{ Torr.}$$

11. Use of Unspecified Gases

11.1. **Resolution.** If the absolute resolution of the gas analyzer is numerically greater than 2 at masses 20, 86, or 136, or than 1 amu at mass 43, then gases other than those specified in Sec. 10 may be used to determine four resolution figures throughout the mass range of the analyzer.

11.2. **Mass Range.** If any of the masses 20, 43, 86, and 136 are outside the mass range of the gas analyzer, gases other than those specified in Sec. 10 may be used to determine the resolution at four points within the mass range of the device.

11.3. **Peak Specification.** While gases other than those specified in Section 10 may be used for determining resolution, not any gas may be used. The considerations discussed in Sec. 4 and Appendix C are overriding, and the gas used must yield peaks meeting the requirements there stated.

11.4. **Specified Gases.** Unless the resolution and mass range of the analyzer are limited as described in 11.1 and 11.2 above, neon, krypton, and xenon are to be used for determining resolution.

12. Resolution vs Ionic Mass

For the purposes of Sec. 13 below, the four resolution figures determined in accordance with Sec. 10 and/or Sec. 11 are to be plotted against the corresponding ionic mass-to-charge ratios. A smooth curve is to be drawn through the four points. From the curve, determine the masses at which the absolute resolution of the gas analyzer is 2, 1, and $\frac{1}{2}$ (amu).

If the resolution does not vary by more than 15% from one end to the other of the mass range of the gas analyzer, the mass range for which the resolution is 1 (amu) (i.e., the "unity resolution" range), is to be determined. See Sec. 14 below.

13. Statement of Resolution

Since resolution (see Sec. 5) may be a function of mass-to-charge ratio, and also of sensitivity,

(a) the resolution of vacuum gas analyzers is to be given by stating the respective mass numbers at which the absolute resolution is 2, 1, and $\frac{1}{2}$ (amu). However, if resolution is independent of mass as specified in Sec. 12 above, the resolution is to be stated by giving the mass range for which the absolute resolution is 1 (amu);

(b) the resolution of vacuum gas analyzers is to be given by a statement of the appropriate resolution figures *and* a statement of the $\text{MDP}(N_2)$ which exists during the determination of resolution.

14. Sensitivity and Resolution Adjustment

Note: Refer to Sec. 5.

In 8.2.12, the gas analyzer under test is adjusted "so as to maximize nitrogen peak height, or as otherwise specified to optimize analyzer performance." The alternatives are necessitated by the different characteristics of the various types of mass spectrometer type gas analyzer. For some, the sensitivity is maximized ("maximum nitrogen peak height") and the resolution is then affected, to a degree, by this maximization. In other types of analyzer, the resolution adjustment takes priority and sensitivity is affected, to a degree, by this adjustment.

Since maximization of sensitivity may limit resolution, nothing in this standard shall be construed to mean that sensitivity for nitrogen must be maximized. The sensitivity may be adjusted to some lesser value and the resolution of the analyzer then determined. Conversely, the resolution may be adjusted in a specified or desired manner and the sensitivity for nitrogen then determined, provided that all the controls except the scanning control and the attenuator remain in the preexisting condition. In such case, it may be necessary to first employ the procedures of Sec. 10 and then those of Sec. 8.

15. Discrimination

15.1. Discrimination shall be reported by presenting a plot of the sensitivities for neon, nitrogen, krypton, and xenon against the respective isotopic mass-to-charge ratios. See Secs. 8.2.20, 8.3.21, and 8.5.1. A smooth curve shall be drawn through the points or as indicated by the relative position of the points.

Appendix A: Symbol for Peak Width

The symbol W is used in this standard to designate peak width, in atomic mass units, and peak width is used to determine resolution. The symbol ΔM or Δm has also been used to designate a certain atomic mass difference, and this mass difference is used to determine resolution. The following discussion will show the close relationship, even identity, of W and ΔM .

Historically, spectral resolution was first studied in connection with optical "line" spectra. The spectra were observed visually. Resolving ability of the spectrometer was accordingly defined by two lines that could "just" be distinguished visually to be "separate"; various criteria were used to determine when two lines were "just" separated. The difference in wavelength, $\Delta\lambda$, of the two lines referred to above was used to determine resolution. The first mass spectrometers used photographic plates to record the mass-spectral "lines"; and there were good physical reasons for defining resolution by a ΔM exactly analogous to $\Delta\lambda$.

Now the value of ΔM , as of $\Delta\lambda$, will depend on the criterion for determining separation of lines. In mass spectrometry, a very convenient and useful criterion is that of (just) "complete" separation. For this criterion, W and ΔM are equal (the same number of mass units). This can be seen from a study of the idealized graphical peaks of Fig. 7. With the usual assumption that nearby peaks have equal bases, and the assumption of idealized triangular peaks, the geometry is simple. The peak base width is taken as being 2 amu. If the masses of the two peaks differ by just 2 amu, the bases of the peaks touch. The peaks are (just) completely separated, and, as stated ΔM equals W . If ΔM is greater than W , a gap appears between the bases of the peaks. If ΔM is less than W , the peaks overlap, as shown by the dashed lines, and "resolution" begins to be lost.

If ΔM is defined for a condition which yields less than complete peak separation, a W can always be defined, in theory, at such a location (higher on the peak) as to be equal to ΔM .

Appendix B: Use of Neon for MDPP

The determination of MDPP involves the determination of two quantities: (1) the peak-to-peak noise; (2) the partial pressure of a (specified) gas which gives an output equal to the noise.

Instruments in common use have MDPP's of 10^{-13} Torr and sometimes lower. For practical purposes, the measurement of such pressures is not feasible. Therefore, the output of the analyser is determined at some higher pressure; the response at lower pressures is calculated on the assumption of a linear relationship between partial pressure and output. However, it is not considered desirable from a standards viewpoint to extrapolate for more than about two decades of pressure. In other words, pressures should be *measured* in the

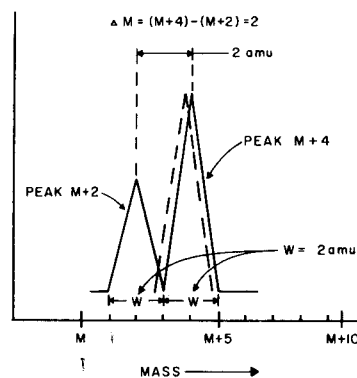


FIGURE 7. Relation of ΔM to W .

10^{-11} Torr range and not at much higher levels, for instruments having about 10^{-13} Torr MDPP.

In the past, the gas specified in defining MDPP has been nitrogen (N^{28}). However, it is extremely difficult to establish a partial pressure of 10^{-11} Torr of nitrogen in a vacuum system. Moreover, even a baked system may have carbon monoxide (CO^{28}) present at a partial pressure of 10^{-11} Torr or greater. The CO^{28} will then be indistinguishable from N^{28} .

To avoid the two problems mentioned above, neon was chosen as the gas to be specified for determining MDPP. Ordinary neon contains an isotope of mass 21 which is present to the extent of 0.265%, or 1/400, of the total gas. If then, the total neon pressure in a system is *measured* to be 10^{-8} Torr, the mass 21 isotope will have a partial pressure of $1/400 \times 10^{-8}$ or about 3×10^{-11} Torr. A pressure of 10^{-8} Torr can be accurately and readily measured by commercially available ionization gauge tubes and controls. Moreover, there are no common residual gases of mass 21 that will normally be present in a vacuum system.

The use of neon, rather than nitrogen, for determination of MDPP, thus eliminates the two problems of pressure measurement and residual gas interference.

Appendix C: Peak Characteristics for Resolution Determinations

C1. Introduction. When a graphical mass spectrum does not have an abscissa linear in mass number, then, as pointed out in 4.1, and discussed in 4.2, Eq. (1), 4.1 must be used for determining absolute resolution. Equation (1) may also be required if other than the gases specified in this standard are used for determining resolution; see Sec. 11. This appendix discusses restrictions on the shape of peaks used for evaluating Eq. (1) and also restrictions on the values of ΔM of that equation.

C2. Reference Base Line. (Refer to Fig. 8.) For the application of Eq. (1), the reference base line shall be drawn above and parallel to the zero output base line,

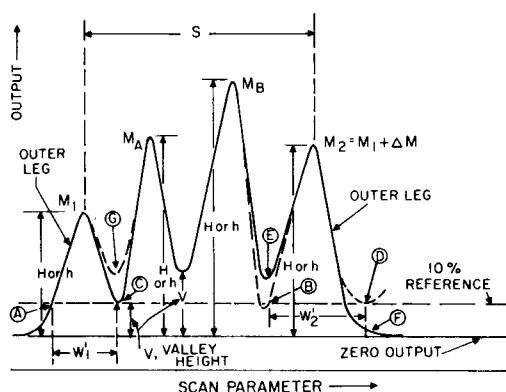


FIGURE 8. Restrictions on peak shape.

the distance above the zero output base line being 10% of either (a) the height of peak M_1 or (b) the height of peak M_2 .

C3. Peak Legs. If the choice is (a) in C2 above, then at least one of the legs of peak M_1 shall intersect the reference base line. If the choice is (b), then at least one leg of M_2 shall intersect the reference base line. See A and B of Figure 8.

C4. Valley Height. If the choice is (a) in C2, above; and both legs of M_1 do not intersect the reference base line, then the nonintersecting leg shall at least be tangent to the reference base line. If the choice is (b) and both legs of M_2 do not intersect the reference base line, then the non-intersecting leg shall at least be tangent to the reference base line. See C and D in Fig. 8. In other words, the valley height, v , for the peak chosen in C2, shall not exceed 10% of the appropriate peak. If neither choice results in the just stated relation of valley and reference base line, M_1 and M_2 do not permit a determination of resolution in the sense of this standard. Referring to Fig. 8, the M_1 peak as shown by the full line

is suitable for choice (a) in C2. (No valley height restriction is placed on the M_2 peak.) However, if the M_1 peak were of the shape indicated at G by the dashed line, it would not be suitable. The M_2 peak, as shown by the full line, would not be suitable for choice (b) in C2. However, if it had the shape shown at B and D by the dashed line, it would be suitable. (No valley restriction is placed on the M_1 peak.)

C5. Mass Difference. With reference to Eq. (1), ΔM , that is, $M_2 - M_1$, shall not exceed

- 1 mass unit for M_1 between 1 and 10 mass units,
- 2 mass units for M_1 between 11 and 50 mass units,
- 3 mass units for M_1 between 51 and 100 mass units,
- 4 mass units for M_1 between 100 and 200 mass units.

C6. Peak Width. The peak width W' , to be used in connection with Eq. (1), shall be measured along the chosen reference base line and between the points of intersection or tangency with the legs of peak M_1 , if the choice is (a) of C2, or with the legs of peak M_2 , if the choice is (b) of C2. The units of W' may be inches, centimeters, volts, cycles per sec, etc.

References

- ¹ See Appendix A.
- ² See Appendix B for a discussion of the choice of neon as the specific gas.
- ³ J. R. Walton and A. E. Cameron, "The Isotopic Composition of Atmospheric Neon", 13th Annual Conference on Mass Spectrometry and Allied Topics, A. S. T. M. Committee E-14, May, 1965. This paper gives the following abundances for neon (to three significant figures):

Ne ²⁰	90.5%
Ne ²¹	0.265
Ne ²²	9.22
- ⁴ R. L. Summers, "Empirical Observations of the Sensitivity of Hot Cathode Ionization Type Vacuum Gages," NASA TN D-5285, National Aeronautics and Space Administration, Washington, D. C., 1969, p. 35.
- ⁵ *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Company, 44th ed., 1962-1963.