

# INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

APPLIED CHEMISTRY DIVISION  
COMMISSION ON ATMOSPHERIC CHEMISTRY\*

## GLOSSARY OF ATMOSPHERIC CHEMISTRY TERMS

(Recommendations 1990)

*Compiled and prepared for publication by*

JACK G. CALVERT

Atmospheric Chemistry Division

National Center for Atmospheric Research, Box 3000, Boulder, CO 80307, USA

\*Membership of the Commission during the period 1986–1990 in which the report was prepared was as follows:

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# Glossary of atmospheric chemistry terms (Recommendations 1990)

## Synopsis

Over 620 atmospheric chemistry terms which are in common use by the international research community in the atmospheric sciences are defined. The diversified nature of the scientists involved in research in atmospheric chemistry (chemists, meteorologists, physicists, biologists, engineers, and others) requires that special attention be paid to the consistency of the terminology employed. Where alternative terms are in common use to describe a given process, piece of equipment, feature, or quantity used in atmospheric chemistry, recommended choices of the IUPAC Commission on Atmospheric Chemistry are given; these are consistent with the other IUPAC publications and recommendations on nomenclature. The range of terms includes composition of the atmosphere, clouds, solar radiation, chemical and physical changes in atmospheric components, instrumentation employed in analysis of the atmospheric components and in air quality control, and in effects of certain trace gases on materials, plants, and animals.

## INTRODUCTION

The present document was prepared as part of a project of the IUPAC Commission on Atmospheric Chemistry. It was the judgment of this Commission that the unambiguous definition of terms and units employed by the international research community in atmospheric chemistry is essential to the achievement of reliable communications between all parties. The diversified nature of the scientists involved in research in atmospheric chemistry, chemists, meteorologists, physicists, biologists, engineers, and others, points to the very special need for a definition of the common terms employed by each specialist with recommendations where alternative terms or units are in use today. In addition to the definition of terms, some examples are given in many cases to illustrate the use of the specific term in atmospheric chemistry. It is hoped that the reader will be tolerant of the inclusion in this Glossary of some terms which are obvious to the specialist in the area of their use, but are unclear to many others who work actively in other areas associated with atmospheric chemistry. In order to enhance the convenience of this Glossary to the user and in view of the specialized nature of many of the atmospheric chemistry terms, we have repeated here the definitions of many terms which appear in other IUPAC publications, rather than including only a reference to the IUPAC publication. All terms taken from the IUPAC *Compendium of Chemical Terminology*, Blackwell Scientific Publications, 1987, commonly referred to as the "Gold Book", are preceded by the designation **GB** (**Gold Book**) in this Glossary. In cases where the definition given here is different from that given by some other IUPAC publication, we have taken care to ensure the compatibility of the definitions while including portions of the definition which are peculiar to atmospheric chemistry.

It is the hope of this Commission that the Glossary will serve the Atmospheric Chemistry research community and lead to a more precise and uniform choice of common terms in the communication between atmospheric scientists around the world.

In the preparation of this document, the members of the Commission relied not only on their own experience and knowledge, but we are grateful to our many colleagues in the field of atmospheric chemistry and the members of the related IUPAC Commissions (Chemical Kinetics: I.4; Molecular Structure and Spectroscopy: I.5; Photochemistry: III.3; Analytical Nomenclature: V.3), IUPAC Divisions (Physical Chemistry: I; Inorganic Chemistry: II; Organic Chemistry: III; Macromolecular: IV; Analytical Chemistry: V; Applied Chemistry: VI; Clinical Chemistry: VII), and the Interdivisional Committee on Nomenclature and Symbols who reviewed the material and provided helpful suggestions. We also made extensive use of several sources of information: the IUPAC *Compendium of chemical terminology* (1987); the IUPAC book on *Quantities, units and symbols in physical chemistry* (1988); *Air quality --Performance characteristics and related concepts for air quality measuring methods*, International Standard, ISO 6879-1983 (E); *Air quality--General aspects--Units of measurement*, International Standard, ISO 4226-1980 (E); *Gas analysis-- Vocabulary*, First edition, 1984, International Standard, ISO 7504; *Air quality--General Aspects--Vocabulary*, First edition, 1980, International Standard, ISO 4225; *Standard definitions of terms relating to atmospheric sampling and analysis*, ANSI/ASTM D 1356-73A.

## GLOSSARY OF ATMOSPHERIC CHEMISTRY TERMS

**Abatement:** Action taken to reduce air pollution which involves the use of control equipment or some new process. This refers to a reduction or lessening as opposed to elimination of a type of discharge or pollutant.

**Absorbance:** The logarithm (must be specified as to base 10, lg, or base e, ln) of the reciprocal of transmittance [ $\ln(I_0/I_t)$  or  $\lg(I_0/I_t)$ ], where  $I_0$  and  $I_t$  are the monochromatic radiances (intensities) of light incident on and transmitted through, respectively, a sample which is usually contained in a sample cell.

**Absorber:** A device used commonly for sampling by absorption in which a gaseous or liquid material is removed from another gas or liquid by selective absorption; these include: scrubber, impinger, packed column, spray chamber, etc. (**GB**<sup>\*</sup>) A substance used to absorb energy from any type of radiation.

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\*Text which is preceded by the designation **GB** in this Glossary was taken directly from the IUPAC Compendium of Chemical Terminology, Blackwell Scientific Publications, 1987, the "Gold Book".

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**Absorptance, absorption-factor:** (**GB**) The ratio of absorbed to incident radiant or luminous flux.

**Absorption:** The process of one material (absorbent) being retained by another (absorbate); this may be the physical solution of a gas, liquid, or solid in a liquid, attachment of molecules of a gas, vapour, liquid, or dissolved substance to a solid surface by physical forces, etc. In spectrophotometry, absorption of light at characteristic wavelengths or bands of wavelengths is used to identify the chemical nature of molecules, atoms or ions and to measure the concentrations of these species. **GB:** The transfer of a component from one phase to another.

**Absorption coefficient:** Quantity used to specify the absorption of light at a given wavelength by a pure compound; it is the constant  $\epsilon$  which appears in the Beer-Lambert law:  $\lg(I_0/I_t) = [A]l\epsilon$ , where  $I_0$  and  $I_t$  are the incident and transmitted monochromatic radiances (intensities), respectively, for an optical path of length  $l$  and uniform concentration of absorbing compound  $[A]$  (commonly  $\text{mol L}^{-1}$ , coherent SI units;  $\text{mol m}^{-3}$ ). The coefficient  $\epsilon$  is sometimes called the (decadic) molar absorption coefficient. Although it is sometimes referred to as the extinction coefficient, this is not a good practice since *extinction* strictly implies the sum of absorption and scattering. There are several useful forms of this relation which are used in describing light absorption. When napierian (natural) logarithms are used, the symbol  $\kappa$  is recommended with the name napierian molar absorption coefficient or molar cross section. Pressure of a gas (STP) may be used rather than concentration, etc. See also *absorption cross section*. The specific form of the law employed (base of the logarithms, concentration, and pathlength units) must be stated with absorption coefficient data derived from it if the data are to be of use to the scientific community.

**Absorption cross section:** A constant ( $\sigma$ ) in the following relation describing the absorption of light of a given wavelength:  $\ln(I_0/I_t) = [A]l\sigma$ ; here  $I_0$  and  $I_t$  are the monochromatic radiances (intensities) of the incident and transmitted light,  $[A]$  is the concentration (molecules  $\text{cm}^{-3}$ ), and  $l$  is the path length (cm);  $\sigma$  (units of  $\text{cm}^2/\text{molecule}$  commonly) is related to the molar cross section  $\kappa$  by:  $\sigma = \kappa/N_A$  where  $N_A$  is the Avogadro constant ( $6.02213 \times 10^{23} \text{ mol}^{-1}$ ).

**Absorption line:** A narrow range of wavelengths in which a substance absorbs light; a series of discrete absorption lines can be used as an unambiguous identification for many relatively simple chemical species.

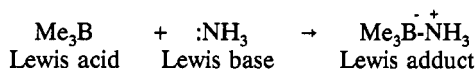
**Absorption spectrum:** The wavelength dependence of the absorption cross section (or absorption coefficient); usually represented as a plot of absorption cross section versus wavelength  $\lambda$  (or  $1/\lambda$ ) of the light.

**Accommodation coefficient:** Also sticking coefficient. A measure of the efficiency of capture of molecules or atoms which collide with aerosol particles, cloud droplets, etc. The accommodation coefficient is the fraction of the collisions which result in the capture of the molecules (atoms, radicals, etc.) by the particle, cloud droplet, etc.; fraction of colliding molecules which are not reflected but which enter the surface of an aqueous aerosol.

**Accretion:** The process by which aerosols grow in size by external addition of various chemical species; a form of agglomeration.

**Accuracy:** The closeness of agreement between the true value and the measured value. The definition given by the ISO International Standard for reference: Agreement between a single measured value,  $\hat{C}_a$ , and the value of air quality characteristic,  $C_a$ , itself, or the accepted reference value; accuracy denotes the extent to which bias and random errors are absent.

**Acid:** A species which reacts in liquid water to generate hydrogen ions (conventionally represented as cations  $H^+$  or hydronium,  $H_3O^+$ ); anions (e.g., sulphate,  $SO_4^{2-}$ ; nitrate,  $NO_3^-$ ) which were associated with the  $H^+$  in the acid are also released. Important acids in the atmosphere include sulfuric acid ( $H_2SO_4$ ), nitric acid ( $HNO_3$ ), and organic acids (e.g., formic acid,  $HCO_2H$ ; acetic acid,  $CH_3CO_2H$ , etc.). **GB: Brønsted acid:** A molecular entity capable of donating a proton to a base, (i.e. a "proton donor") or the corresponding chemical species. For example:  $H_2O$ ,  $H_3O^+$ ,  $CH_3CO_2H$ ,  $H_2SO_4$ ,  $HSO_4^-$ . **GB: Lewis acid:** A molecular entity (and the corresponding chemical species) that is an electron-pair acceptor and therefore able to react with a Lewis base to form a Lewis adduct, by sharing the electron pair furnished by the Lewis base. For example:



**GB: Hard acid:** A Lewis acid with an acceptor centre of low polarizability. It preferentially associates with hard bases rather than with soft bases, in a qualitative sense. For example, the hard O- (or N-) bases are preferred to their S- (or P-) analogues. Conversely a soft acid possesses an acceptor centre of high polarizability and exhibits the reverse preference of a partner for co-ordination. These preferences are not defined in a quantitative sense.

**Acid deposition:** The acids deposited by transfer from the atmosphere either by precipitation (rain, fog, snow, etc.), called *wet deposition*, or by direct transfer to the surface of the earth induced by the flow of acid-containing air masses over the earth's surface, called *dry deposition*.

**Acid rain:** Rain with pH values < about 5; commonly results from acids formed from pollutants. "Pure" rain water equilibrated with atmospheric  $CO_2$  and naturally occurring acids in relatively clean air usually has a pH > 5.

**Actinic flux ( $S_\lambda$ ):** The quantity of light available to molecules at a particular point in the atmosphere and which, on absorption, drives photochemical processes in the atmosphere. It is calculated by integrating the spectral radiance  $L(\lambda, \theta, \phi)$  over all directions of incidence of the light,  $\int_\theta \int_\phi \{L(\lambda, \theta, \phi)/(hc/\lambda)\} \sin\theta \, d\theta \, d\phi$ . If the radiance is expressed in  $J \, m^{-2} \, s^{-1} \, sr^{-1} \, nm^{-1}$  and  $hc/\lambda$  is the energy per quantum of light of wavelength  $\lambda$ , the actinic flux has units of quanta  $cm^{-2} \, s^{-1} \, nm^{-1}$ . This important quantity is one of the terms required in the calculation of *j*-values, the first order rate coefficients for photochemical processes in the sunlight-absorbing, trace gases in the atmosphere. The actinic flux is determined by the solar radiation entering the atmosphere and by any changes in this due to atmospheric gases and particles (e.g., Rayleigh scattering, absorption by stratospheric ozone, scattering and absorption by aerosols and clouds), and reflections from the ground. It is therefore dependent on the wavelength of the light, on the altitude, and on specific local environmental conditions. The actinic flux has borne many names (e.g., flux, flux density, beam irradiance, actinic irradiance, integrated intensity) which has caused some confusion. It is important to distinguish the actinic flux from the spectral irradiance, which refers to energy arrival on a flat surface having fixed spatial orientation ( $J \, m^{-2} \, s^{-1} \, nm^{-1}$ ) given by  $E(\lambda) = \int_\theta \int_\phi L(\lambda, \theta, \phi) \cos\theta \sin\theta \, d\theta \, d\phi$ . The actinic flux does not refer to any specific orientation because molecules are oriented randomly in the atmosphere. This distinction is of practical relevance: the actinic flux (and therefore a *j*-value) near a brightly reflecting surface (e.g., over snow, or above a thick cloud) can be a factor of three higher than that near a non-reflecting surface. The more descriptive name of *spectral spheradiance* is suggested for the quantity herein called actinic flux. See also *flux density*, *photon*.

**Activity, absolute: (GB)** The absolute activity  $\lambda_B$  of a substance B in a mixture of substances B, C, ... is a number defined by

$$\lambda_B = \exp(\mu_B/RT) \text{ or } \mu_B = RT \ln \lambda_B$$

where  $\mu_B$  is the *chemical potential* of the substance B and *R* is the gas constant.

**Activity, relative: (GB)** Of a solute substance B in a solution (especially in a dilute liquid solution) containing molalities  $m_B, m_C, \dots$ , of solute substances B, C, ..., in a solvent substance A,  $a_B$  is a number defined in terms of the absolute activity  $\lambda_B$  by

$$a_B = (\lambda_B/m^\ominus)/(\lambda_B/m_B)^\infty = m_B\gamma_B/m^\ominus \quad (T, p \text{ constant})$$

or in terms of the chemical potential  $\mu_B$  by

$$\begin{aligned} RT\ln a_B &= \mu_B - RT\ln m^\ominus - (\mu_B - RT\ln m_B)^\infty \\ &= RT\ln(m_B\gamma_B/m^\ominus) \end{aligned}$$

where  $m^\ominus$  is a standard value of molality (usually chosen to be 1 mol kg<sup>-1</sup>),  $\gamma_B$  is the activity coefficient of B,  $R$  is the gas constant,  $T$  is the thermodynamic temperature, and  $p$  is the pressure. The superscript  $\infty$  denotes infinite dilution.

**Activity coefficient:** The coefficient ( $\gamma$ ) measures the degree of departure of a component in solution from ideal behavior. It relates concentration  $[A]$  and activity ( $a$ ) for a substance in solution:  $a = \gamma[A]$ . The concentrations and activities of components are often given in molal units (mol kg<sup>-1</sup> of solute). The activity coefficient,  $\gamma$ , is usually determined empirically; it depends not only upon the concentration of the substance but on its particular properties and on the concentration and kind of other substances present. As the concentration of the solute approaches zero, the activity coefficient approaches unity. **GB:** The activity coefficient  $\gamma_B$  of a single substance B in a solution (especially in a dilute liquid solution) containing molalities  $m_B, m_C, \dots$ , of solute substances B, C,  $\dots$ , in a solvent substance A, is a number defined in terms of the absolute activity  $\lambda_B$  of the solute substance B in the solution by

$$\gamma_B = (\lambda_B/m_B)/(\lambda_B/m_B)^\infty \quad (T, p \text{ constant})$$

or in terms of the chemical potential  $\mu_B$  by

$$RT\ln(m_B\gamma_B) = \mu_B - (\mu_B - RT\ln m_B)^\infty \quad (T, p \text{ constant})$$

where the superscript  $\infty$  denotes infinite dilution. The activity coefficient  $f_B$  of a substance B in a liquid or solid mixture containing mole fractions  $x_B, x_C, \dots$ , of the substances B, C,  $\dots$ , is a number defined in terms of the absolute activity  $\lambda_B$  of the substance B in the mixture by

$$f_B = \lambda_B/\lambda_B^*$$

where  $\lambda_B^*$  is the absolute activity of the pure substance B at the same temperature and pressure, or in terms of the chemical potential  $\mu_B$  by

$$RT\ln(x_B f_B) = \mu_B - \mu_B^*$$

and  $\mu_B^*$  is the chemical potential of the pure substance B at the same temperature and pressure.

**Adiabatic lapse rate:** The rate of decrease in temperature with increase in altitude of an air parcel which is expanding slowly to a lower atmospheric pressure without exchange of heat; for a descending parcel it is the rate of increase in temperature with decrease in altitude. Theory predicts that for dry air it is equal to the acceleration of gravity divided by the specific heat of dry air at constant pressure (approximately 9.8 °C/km). The moist adiabatic lapse rate is less than the dry adiabatic lapse rate and depends on the moisture content of the air mass.

**Adsorbate:** A molecular species of gas, dissolved substance or liquid which adheres to or is adsorbed in an extremely thin surface layer of a solid substance. **GB:** The material accumulated on the surface of an adsorbent by the process of adsorption.

**Adsorbent:** An adsorbent is the solid material to which another species is adsorbed in a surface layer. **GB:** A condensed phase at the surface of which adsorption may occur.

**Adsorber:** Solid material used to capture either a gas or liquid; often activated carbon is employed as the solid because of its high surface area per unit mass.

**Adsorption:** The process by which molecules of gas, dissolved substances, or liquids adhere to the surface of solids through either weak physical forces (physical adsorption) or stronger chemical forces (chemical adsorption). **GB:** The enrichment (positive adsorption, or briefly, adsorption) of one or more components in an interfacial layer.

**Advection:** The transport of air, its properties (such as heat), trace materials, fog, cold air, etc., solely by

mass motion of the atmosphere, generally in a horizontal direction.

*Aeration:* The process by which a volume filled with a liquid becomes permeated with air or another gas; aeration is often accomplished by spraying the liquid into the air, bubbling air through a liquid, or agitating the liquid to promote surface absorption of air.

*Aerometer:* Instrument used to measure the density of gases.

*Aerometric measurements:* Measurements of the temperature, pressure, air motion (velocity vectors), or other physical measurements to characterize an air mass.

*Aerosol:* Mixtures of small particles (solid, liquid, or a mixed variety) and the carrier gas (usually air); owing to their size, these particles (usually less than 100  $\mu\text{m}$  and greater than 0.01  $\mu\text{m}$  in diameter) have a comparatively small settling velocity and hence exhibit some degree of stability in the earth's gravitational field. An aerosol may be characterized by its chemical composition, its radioactivity, the particle size distribution, the electrical charge and the optical properties. **GB:** Aerosols are dispersions in gases. In aerosols the particles often exceed the usual size limits for colloids. If the dispersed particles are solid, one speaks of "aerosols of solid particles", if they are liquid of "aerosols of liquid particles". The use of the terms "solid aerosol" and "liquid aerosol" is discouraged. An aerosol is neither "solid" nor "liquid", but if anything, gaseous.

*Agglomeration:* The growth of particles in size due to an attachment of other particles following collisions. The term refers to aerosol particles, cloud droplets, etc.

*Air, composition of pure:* The composition of air is variable with respect to several of its components (e.g.,  $\text{CH}_4$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ) so "pure" air has no precise meaning; it is commonly considered to be air which is free of dust, aerosols, and reactive gaseous contaminants of anthropogenic origin. The composition of the major components in dry air is relatively constant (percent by volume given): nitrogen, 78.084; oxygen, 20.946; argon, 0.934; carbon dioxide, 0.033; neon, 0.0018; helium, 0.000524; methane, 0.00016; krypton, 0.000114; hydrogen 0.00005; nitrous oxide, 0.00003; xenon, 0.0000087. The concentration of carbon dioxide, methane, nitrous oxide, the chlorofluorocarbons, and some other species of anthropogenic origin are increasing measurably with time. Relative clean air which is free of most reactive anthropogenic pollution ( $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$ , non-methane hydrocarbons, etc.), often used as a reference sample in the calibration and operation of instruments, is purchased under the designation of *zero air*.

*Air mass:* A qualitative term to describe a widespread body of air with approximately uniform characteristics which had been identified at a given time over a particular region of the earth's surface. Sometimes an air mass is marked by inert tracers such as  $\text{SF}_6$  which may be added to it. The composition of a given air mass undergoes alteration as it migrates, chemical changes occur, compounds are removed by dry and wet deposition, and new impurities are added to the mass.

*Air monitoring station:* A site at which monitoring of the concentration of one or more pollutants is carried out (e.g., the BAPMoN stations, Background Air Pollution Monitoring Network of the WMO, World Meteorological Organization).

*Air pollutant:* A substance, gaseous material or aerosol which has been introduced into the air (either by human activity or by natural processes) in sufficient concentration to produce a measurable effect on humans, animals, vegetation, or materials (monuments, etc.):  $\text{SO}_2$ ,  $\text{NO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{CO}$ , hydrocarbons, etc.

*Air pollution:* Usually the presence of substances in the atmosphere, resulting either from human activity or natural processes, present in sufficient concentration, for a sufficient time and under circumstances such as to interfere with comfort, health or welfare of persons or the environment.

*Air pollution control:* Measures taken to control the purity of the air to some degree specified by law.

*Air pollution control district:* A geographical region designated by law in which the emissions of some specified air pollutants are controlled to a degree specified by law.

*Air pollution index or air quality index:* A mathematical combination of the concentrations of air pollutants (weighted in some fashion to reflect the estimated health impact of the specific pollutant) which gives an approximate numerical measure of the quality of the air at a given time. These indices have little scientific basis but have been used to inform the public (in a qualitative fashion) of the degree of pollution present at a given time. It is recommended that the actual measured pollutant concentrations be used by all information services when possible with simultaneous reference given to the corresponding concentrations which are considered by health authorities to be hazardous to human health.

**Air pollution survey:** A study of the concentrations and geographical distribution of specified air pollutants in a given area and an assessment of the damage, if any, which the pollutants have caused.

**Air quality characteristic:** One of the quantifiable properties relating to an air sample: concentration of a constituent, wind speed, temperature, etc. The *quantity of air quality characteristic* is the true value of the characteristic being investigated; it is recognized that in practice, this value can only be approximated by existing methods.

**Air resource management:** The detailed planning and the implementation of air pollution control programs designed to preserve the health and welfare of the people in the region, the plant and animal life, physical property, good visibility, and other factors which determine the air quality and the maintenance of an aesthetically acceptable environment.

**Air sampling network:** A number of air sampling stations which are established in a given geographical region at which measurements of both pollutant concentrations and meteorological quantities (wind speed, direction, rain fall, humidity, etc.) are made to determine the extent and the nature of the air pollution and to establish trends in the concentrations of the air pollutants with time.

**Aitken particles:** Aerosol particles below  $0.1\ \mu\text{m}$  in diameter. These generally are the most numerous among all particles in the air. Their concentrations can be determined with the Aitken counter which measures total particle number density. Owing to their small size, Aitken particles contribute little to the total mass concentration of all aerosol particles; this is determined primarily by particles of diameter  $> 0.1\ \mu\text{m}$ .

**Albedo:** The fraction of the energy of electromagnetic radiation reflected from a body (or surface) relative to the energy incident upon it. The reflection of light from a surface is, of course, dependent on the wavelength of the light, the nature of the surface, and its angle of incidence with the surface. The term *albedo* usually connotes a broad wavelength band (visible, ultraviolet, or infrared), whereas the terms *reflectivity* and *spectral albedo* are used to describe the reflection of monochromatic (single wavelength or small band of wavelengths) radiation.

**Aldehyde:** A class of organic compound of general formula:  $\text{R}(\text{C}=\text{O})\text{H}$ , where R is an hydrogen atom or hydrocarbyl group (e.g.,  $\text{CH}_3$ ,  $\text{C}_2\text{H}_5$ , etc.). These are products of hydrocarbon oxidation. The simplest aldehydes are formaldehyde (methanal,  $\text{CH}_2\text{O}$ ), acetaldehyde (ethanal,  $\text{CH}_3\text{CHO}$ ), and propionaldehyde (propanal,  $\text{CH}_3\text{CH}_2\text{CHO}$ ). Aldehydes absorb sunlight ( $\lambda < 330\ \text{nm}$ ) and generate radicals. They also react rapidly with HO-radicals in the atmosphere to produce acyl (RCO) and acylperoxyl ( $\text{RCOO}_2$ ) radicals. Formaldehyde is the most abundant aldehyde in the atmosphere (formed from the natural hydrocarbon,  $\text{CH}_4$ , as well as other hydrocarbons) where its mixing ratios are often  $> 0.2\ \text{ppbv}$  even in relatively clean air. Acetaldehyde is a major precursor to peroxyacetyl nitrate (PAN) in the troposphere.

**Alert levels:** Designated concentrations of certain key pollutants at which some degree of danger to public health is expected. In many areas in which a relatively high level of pollution is often encountered, several levels of alert are often established. For example, a first alert may signify a potential problem exists; a second alert becomes a signal for the curtailment of certain significant emission sources; the third alert signifies the need for some specified emergency action which must be taken to ensure the public safety.

**Aliquot:** A representative portion of the whole.

**Ambient air:** The outdoor air in the particular location.

**Ambient air quality:** A general term used to describe the quality of the outside air. Usually adjectives such as good, fair, bad, etc. are used by the media to describe this; often some form of *air pollution or air quality index* is employed to determine the specific descriptive term to be used. These are very qualitative terms of little or no scientific value. See also *air pollution index, air quality index*.

**Ames/salmonella test:** A screening test employed in predicting the mutagenic and the potential carcinogenic activities of chemicals in the environment. It employs Ames test strains of salmonella bacteria (*his*<sup>-</sup>) which lack the ability to produce histidine. The compound to be tested, the bacteria and a small amount of histidine (insufficient to permit colony growth but enough to allow sufficient growth for expression of mutations) are added to agar. The bacteria are allowed to incubate for about 63 hours at  $37\ ^\circ\text{C}$ . If a significant increase in colonies above background is observed in the sample containing the test compound, then it is concluded that the chemical tested is a direct mutagen for the particular Ames strain of bacteria. This is taken as a qualitative indication of the *possible* carcinogenic activity of this chemical in other biological systems. This procedure seems to be of qualitative value in a preliminary screening of potential carcinogens.

*Analyser, accuracy of an analysis with:* The ability of a measuring instrument to give indications approaching the true value of the quantity measured.

*Analyser, continuous:* An analyser in which subassemblies operate continuously.

*Analyser, continuous indication:* An analysis with a permanent indication related to the sample concentration. To obtain a continuous indication, the sampling and measuring cell need to be continuous. A time lag may exist between sampling and indication of measured concentration; see *analyser, dead time of*.

*Analyser, dead time of:* Time which elapses between the moment at which a sudden change in concentration (or a new sample) is introduced and the moment at which the detector response indication reaches the measurement threshold of the analyser, a value conventionally fixed at 10% of the final change in indication.

*Analyser, discontinuous:* An analyser with at least one discontinuous subassembly.

*Analyser, discontinuous indication of:* Indication related to the concentration during intervals of time which are not continuous.

*Analyser, fall time of:* When following a change in concentrations from a definite value  $c$  to 0, the time which elapses between the moment when this change is produced and the moment when the indication reaches a value conventionally fixed at 10% of the final change or indication.

*Analyser, measurement threshold of:* The minimum concentration of a substance which produces a quantifiable signal with a given uncertainty.

*Analyser, precision of measurements with:* The quality which characterizes the ability of a device to give for the same value of the quantity measured, indications which agree among themselves, not taking into consideration the systematic errors associated with variations of the indications. *Repeatability* characterizes the ability of a device to give indications which are unaffected by random errors.

*Analyser, range of measurement of:* Range of concentration between the measurement threshold and the maximum usable indication.

*Analyser, resolution of:* A general term which defines the ability of a device to differentiate between adjacent signals.

*Analyser, response time of:* Time which elapses, when there is a stepwise change in the quantity to be measured, between the moment when this change is produced and the moment when the indication reaches a value conventionally fixed at 90% of the final change in indication.

*Analyser, rise time of:* The difference between the response time and the dead time.

*Analyser, selectivity of analyses with:* Ability of a device to exhibit a low or zero sensitivity to analytes (see *interferant*) other than the one it is intended to measure. The selectivity is described by a coefficient of interaction; it is the ratio of the device response to the substance to be measured to that of the interferant, both being at the same concentration; see *Selectivity*.

*Analyser, sensitivity of:* The response of the measuring cell of a system in indicated output units per unit concentration of the component being measured. It is the slope, at the concentration being measured, of the tangent to the calibration curve.

*Analyser, sequential:* A discontinuous analyser in which at least one subassembly operates sequentially.

*Analyser, sequential indication of:* Indication obtained following sequential sampling or received from a sequential cell or from data processing comprising a succession of predetermined repetitive operations (or a combination of the three).

*Analytical function:* Function which relates the measured value  $\hat{C}_a$  to the instrument reading,  $X$ , with the value of all interferants,  $C_i$ , remaining constant. This function is expressed by the following regression of the calibration results.

$$\hat{C}_a = f(X) \quad \left| \quad C_i = \text{constant} \right.$$



The analytical function is taken as equal to the inverse of the calibration function.

*Analytical unit; analyser:* An assembly of sub-units comprising: suitable apparatus permitting the introduction and removal of the gas, liquid or solid to be analysed and/or calibration materials; a measuring cell or other apparatus which, from the physical or chemical properties of the components of the material to be analysed, gives signals allowing their identification and/or measurement; signal processing devices (amplification, recording) or, if need be, data processing devices.

*Aneroid barometer:* An instrument for monitoring the atmospheric pressure in which no liquid is employed, but rather changes in pressure between the atmosphere and a closed vessel bend a diaphragm which moves a pointer on a scale.

*Anticyclone:* A large system of winds that rotate about a centre of high atmospheric pressure, clockwise (viewed from above) in the northern hemisphere and counterclockwise in the southern hemisphere.

*Appearance energy (appearance potential):* Refers to ionization of a molecule or atom by electron collision or photon absorption. In mass spectrometry it has often been reported as the voltage which corresponds to the minimum energy of the electrons in the ionizing beam necessary for the production of a given fragment ion. In photoionization it is the minimum energy of the quantum of light which produces ionization of the absorbing molecule. **GB:** It is recommended that the term *appearance energy* replace the term *appearance potential* and that the energy should be stated in SI units.

*Arrhenius equation:* The equation,  $k = Ae^{-E_a/RT}$ , which describes the rate coefficient ( $k$ ) for an elementary reaction in terms of a preexponential factor  $A$ , activation energy  $E_a$ , temperature  $T$  (K), and gas constant  $R$ .

*Ash:* The solid residue which remains after the combustion of a fuel such as coal. Ash consists largely of heat treated mineral matter, but it may contain some products of the incomplete combustion of the fuel as well.

*Atmosphere (of the earth):* The entire mass of air surrounding the earth which is composed largely of nitrogen, oxygen, water vapour, clouds (liquid or solid water), carbon dioxide, together with trace gases and aerosols; see *air, composition of pure*.

*Atmosphere (unit of pressure measurement):* A unit of pressure measurement which has been employed in describing the pressure of gases in storage tanks. It is roughly related to the average pressure of the atmosphere at sea level. One atmosphere =  $1.01325 \times 10^5 \text{ N m}^{-2}$  (Pa)  $\equiv$  1013.25 mbar  $\equiv$  760 Torr. The use of the atm unit of pressure measurement is no longer recommended by international scientific bodies; it has been recommended that standard pressure be redefined as  $10^5$  Pa.

*Atomize:* To subdivide a liquid into very small particles; methods include: impact with a jet of gas, use of a spinning disk generator, vibrating orifice generator, etc.

*Arrester:* Equipment designed to remove particles from a gaseous medium.

*Aspirator:* Any apparatus that produces a movement of a fluid by suction (e.g., a squeeze bulb, pump, Venturi, etc.)

*Anthropogenic:* Produced by human activities.

*Background concentration (level):* Synonymous with baseline concentration. The concentration of a given species in a pristine air mass in which anthropogenic impurities of a relatively short lifetime are not present. The background concentrations of relatively long-lived molecules, methane, carbon dioxide, halocarbons ( $\text{CF}_3\text{Cl}$ ,  $\text{CF}_2\text{Cl}_2$ , etc.), and some other species continue to rise due to anthropogenic input, so the composition of background air is undergoing continual change. Background concentration of a given species is sometimes considered to be the concentration of that impurity in a given air mass when the contribution from anthropogenic sources under study is absent.

*Baffle chamber:* A chamber used in incinerator design to promote the settling of fly ash and coarse particulate matter by changing the direction and/or reducing the velocity of the gases produced by the combustion of the refuse.

*Bag filter:* A large bag constructed of a suitable fabric which is often tubular in shape, into which a particle-containing air stream flows. Modern bags are constructed of a fabric which is capable of collecting all but very fine particles in the gas stream. The efficiency of the removal of particles of various size ranges

changes with the amount of particles captured by the filter and the filtering time. The bag operates on the same principle as the one on a household vacuum cleaner.

**Baghouse:** An installation which contains many bag filters in parallel so that the resistance to air flow in a large installation is not seriously increased by the addition of these controls.

**Base:** A species which when dissolved in water generates hydroxide ( $\text{OH}^-$ ) ions or is capable of reacting with an acid to form a salt. **GB:** A *Brønsted base* is a molecular entity capable of accepting a proton from an acid (i.e. a "proton acceptor") or the corresponding chemical species. For example:  $\text{OH}^-$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_3\text{CO}_2^-$ ,  $\text{HSO}_4^-$ ,  $\text{SO}_4^{2-}$ . A *Lewis base* is a molecular entity (and the corresponding chemical species) that is able to provide a pair of electrons and thus capable of co-ordination to a Lewis acid, thereby producing a Lewis adduct.

**Baseline in gas chromatography:** Portion of a chromatogram corresponding to the signal delivered by the detector when, under normal conditions of operation, only the carrier gas passes through the detector. The slow desorption of strongly adsorbed substances previously passed through the column may contribute to this baseline position (*column bleed*). **GB:** The signal trace recorded as a function of time in the absence of analyte.

**Beer-Lambert Law:** An equation useful in the description of light absorption by a compound of concentration  $[A]$  (often in  $\text{mol L}^{-1}$ ) and with an optical path length  $l$  (often in cm):  $\lg(I_0/I_t) = [A]l\epsilon$ ; here  $I_0$  and  $I_t$  represent the radiance (intensity) of the incident and the transmitted light, respectively, and  $\epsilon$  is the decadic molar absorption coefficient with common units of  $\text{L mol}^{-1} \text{cm}^{-1}$  coherent SI units  $\text{mol}^{-1} \text{m}^2$ . For a collimated beam having a unique pathlength through the absorbing medium, this law applies to irradiance as well.

**Bias error:** Systematic deviation of the results of a measurement process from the true value of the air quality characteristic. This deviation cannot be detected by merely repeating the method several times under prescribed conditions. **GB:** Characterizes the systematic error in a given analytical procedure and is the (positive or negative) deviation of the mean analytical result from the (known or assumed) true value.

**Bimodal distribution:** The occurrence of two maxima in a frequency distribution.

**Biosphere:** That part of the globe that encompasses all forms of life on the earth. It extends from the ocean depths to a few thousand meters of altitude in the atmosphere, and includes life forms at the earth's surface, in soils, and constituents which exchange materials with atmospheres, oceans, or surfaces.

**Bivane:** A wind vane used in turbulence studies to obtain horizontal and vertical components of the wind vector.

**Blank reading or blank value:** Instrument reading for a zero sample. A reading originating from the matrix, reagents and any residual bias in the measurement instrument or process, but not from the analyte.

**Blowdown:** Hydrocarbons purged during refinery shutdowns and startups which should be piped to storage systems for safe venting, flaring, or recovery. This term also applies to the purging of water in boiler operation, and serves in the control of dissolved solids in the boiler water.

**Bond dissociation enthalpy** (called *bond dissociation energy* in the older literature): The standard enthalpy change ( $\Delta_f H^\circ$ ) which accompanies the dissociation of a specific bond in a molecule; e.g.,  $\text{CH}_4(\text{g}) \rightarrow \text{H}(\text{g}) + \text{CH}_3(\text{g})$ ; a temperature of 298 K is implied unless another temperature is specified. This may be contrasted with the term *bond energy* which refers to the average energy required to break all equivalent bonds in a molecule: e.g., the C-H bond energy in  $\text{CH}_4$  is equal to the  $\Delta_f H^\circ/4$  where  $\Delta_f H^\circ$  refers to the enthalpy change for the overall reaction,  $\text{CH}_4(\text{g}) \rightarrow 4\text{H}(\text{g}) + \text{C}(\text{g})$ . **GB:** The enthalpy (per mole) required to break a given bond of some specific molecular entity by homolysis.

**Boundary layer:** That well-mixed region of the lower atmosphere in which the turbulence is maintained largely by convective buoyancy induced by the upward heat flux originating from the solar-heated surface of the earth. During the afternoon this often extends from 1 to 5 km in height. *Surface boundary layer* is that region of the lower atmosphere where the shearing stress is constant. It is separated by the Ekman layer from the *free atmosphere*, where the behavior of the atmosphere approaches that of an ideal fluid in approximate geostrophic equilibrium (horizontal coriolis force balances the horizontal pressure force at all points in the field).

**Breeching:** The passage or conduit through which the exhaust products of combustion are carried to the stack or chimney.

**Breeze:** A term sometimes used to describe very fine particles of coke. Also a meteorological term for a gentle wind.

**Bridge solution (in pH measurement): (GB)** Solution of high concentration of inert salt, preferably comprising cations and anions of equal mobility, optionally interposed between the reference electrode filling and both the test and standard solution, when the test solution and filling solution are chemically incompatible. This procedure introduces into the operational cell a second liquid junction formed usually in a similar way to the first.

**Brownian motion:** The movement of particles in a colloidal system such as an aerosol caused by collision with the molecules in the fluid in which the particles are imbedded.

$b_{\text{scat}}$ : See *scattering cross section*.

**Bubbler:** An apparatus used to absorb certain water soluble components in a gas stream for later analysis. Usually it involves the use of a glass fritted tube which forces the air into small bubbles of high surface area during operation.

**Calibration component:** A component of a calibration mixture, present in the gaseous or vapour state, quantitatively and qualitatively defined, and used directly for testing and for calibration.

**Calibration function:** Instrument reading,  $X$ , as a function of measurable properties of the air quality characteristic under investigation represented by the reference material, with all interferants,  $C_i$  remaining constant. This may be quantified by the following regression function of the calibration results:

$$X = g(C_a) \quad \left| \quad C_i = \text{constant} \right.$$

A calibration function designated by  $X = C_a s + \text{constant}$ , where the sensitivity  $s$  is constant, is designated a linear function.

$$s = \frac{\partial g(C_a, C_1, C_2, \dots, C_n)}{\partial C_a}$$

If the sensitivity is not a constant, the calibration function is called non-linear. Non-linearity may be expressed by higher order regression coefficients.

**Calibration gas mixture:** A gas mixture of known composition, generally comprising one or more calibration components and a complimentary gas.

**Calibration gas mixture, methods of preparation of:**

- a) **Gravimetric method:** A method in which each component of a mixture is successively added to a gas cylinder which is weighed first empty and then after each addition. The concentration of each component is expressed as a mass ratio or mole ratio.
- b) **Manometric method:** A method in which each component of a mixture is added successively to a gas cylinder previously emptied and where the pressure is measured after each addition. The mole ratio can only be calculated from the pressure data if the deviation from ideality of the particular system is known.
- c) **Static volumetric method:** A method in which a mixture is prepared by combining two or more gases, contained in two or more separate calibrated volumes, all at known temperatures and pressures. The volume ratio of a component in the resulting mixture may be calculated from the known ratios of the calibrated volumes. The calculated volume ratio may differ from the mole ratio if the mixture does not behave ideally.
- d) **Dynamic volumetric method:** A method in which two or more gas streams, flowing at known volume flow rates under specified conditions are combined into a single stream. The volume ratio of any component in the resulting mixture is calculated from the ratio of the volume flow rates. Deviations from ideality of the mixture must be known in order to calculate the mole ratio unless the flow rates are measured in mass flow per unit time for all gases; in this case the mass or mole ratio can be directly calculated.
- e) **Saturation method:** A method in which a stream of gas is passed over or through a substance capable of evaporation or sublimation held at a fixed temperature. At equilibrium the concentration of the substance in the stream of gas will be determined by the vapour pressure of the substance at the temperature given.
- f) **Permeation method:** A method in which a stream of gas is passed over a porous or permeable tube or vessel containing a volatile substance usually present as the liquid and saturated vapour phases. The permeation rate of the substance through the walls of the tube should be constant at any given temperature as long as sufficient liquid and its

vapour remain in the tube. The concentration of the substance in the stream of gas is determined by the rate of flow of the gas stream and the permeation rate of the substance. If the gas flow is measured in terms of mass per unit time and the permeation rate is known in the same units, then the mass ratio or the mole ratio can be calculated. *g) Diffusion method:* A method in which a gas or vapour diffuses through a restriction into a stream of gas flowing at constant rate. If the temperature and pressure of the diffusing species remain constant at the inlet to and within the restriction, the mass rate of flow of the diffusing species will remain constant. *h) Comparison method:* A method in which the concentration of a component in a mixture is measured by comparison with another mixture or other mixtures containing the same component at known concentrations.

*Calibration mixture:* A gaseous or liquid mixture of known composition, generally comprising one or more calibration components and an inert diluent, used directly for testing and calibration of analytical instruments.

*Carbon black:* Finely divided forms of carbon made by the incomplete combustion or thermal decomposition of natural gas, higher molecular weight hydrocarbons or other carbon-containing compounds.

*Carbon dioxide (CO<sub>2</sub>):* Colorless, odorless gas which is the major carbon-containing product of combustion of carbon compounds. Its removal in the atmosphere involves the photosynthetic cycle in plants which convert CO<sub>2</sub> into carbohydrate and other organic molecules important in plant growth, as oxygen is released. It is also removed by the oceans where it is converted to carbonate deposits. Its concentration in the atmosphere varies with position on the earth, season, time of day, etc. However its average mixing ratio in pristine air has increased from about 315 to 340 ppmv during the last 25 years, presumably as a result of increased burning of fossil fuels. Concern has been expressed in the possible effects of this increase on global climate change; see *greenhouse effect*.

*Carbon monoxide (CO):* Colorless, odorless gas which is highly poisonous even at the level of 0.2% in air. It is a product of the incomplete combustion of hydrocarbon fuels, and it is also formed in the clean atmosphere as a result of the oxidation of methane and its oxidation product formaldehyde (CH<sub>2</sub>O); mixing ratios of CO in pristine air masses are usually of the order of 100 ppbv near sea level.

*Carrier gas:* A gas introduced in order to transport a sample for analytical purposes. In gas chromatography it is the gas which is passed continuously through the column and whose passage promotes the elution of the components of the sample. **GB:** The carrier gas together with the portions of the sample present in this phase constitutes the mobile phase.

*Catalysis:* The alteration of the rate of a chemical reaction (usually increase in the rate) by the addition of some substance (the catalyst) which does not undergo a net chemical change. **GB:** Cases occur with certain reactants in which the addition of a substance reduces the rate of a particular reaction, for example, the addition of an inhibitor in a chain reaction or a poison in a catalytic reaction. The term "negative catalysis" has been used for these phenomena, but this usage is not recommended; terms such as *inhibition* or *poisoning* are preferred.

*Ceilometer:* An automatic, recording instrument for reading the height of the cloud-base.

*Cell, continuous measuring:* A measuring cell which operates continuously.

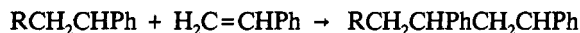
*Cell, discontinuous measuring:* A measuring cell which operates intermittently and not necessarily at fixed time intervals.

*Cell, sequential measuring:* A measuring cell which operates according to a succession of operations on the sample or on the sensitive elements (or on both), these operations being carried out according to one or more repetitive programs.

*Ceramic filter:* A component of a stack sampling system which is suitable for high temperature use; also known as a ceramic thimble.

*Chain reaction:* Chain reactions are characterized by a series of interrelated steps involving initiation, propagation, and termination. If the propagation steps recur a number of times for each initiation step and termination step, the reaction is called a chain reaction. For example, in the Cl<sub>2</sub>-H<sub>2</sub> system which is irradiated within the Cl<sub>2</sub> absorption band, the reaction is initiated by the photodissociation of Cl<sub>2</sub>: Cl<sub>2</sub> + hν → 2Cl. The propagation steps involve the reaction and reformation of Cl atoms: Cl + H<sub>2</sub> → HCl + H; H + Cl<sub>2</sub> → HCl + Cl; eventually termination occurs largely through the reassociation of Cl atoms: 2Cl + M → Cl<sub>2</sub> + M. M is a third body which removes some of energy released by the formation of Cl<sub>2</sub> and allows it to be stabilized. The Cl<sub>2</sub>-H<sub>2</sub> system can have a *chain length* of up to a million at low light intensities; i.e., 10<sup>6</sup> molecules of HCl

can form for each  $\text{Cl}_2$  molecule photodissociated. In the atmosphere the oxidation of  $\text{NO}$  to  $\text{NO}_2$  which occurs in the sunlight-irradiated mixture of  $\text{NO}_x$  and hydrocarbons, a complex series of chain reactions occur involving  $\text{HO}\cdot$ ,  $\text{HO}_2\cdot$ , and  $\text{RO}_2\cdot$ -radicals,  $\text{NO}$ , hydrocarbons, and their oxidation products. **GB:** In chain polymerization reactions, reactive intermediates of the same type, generated in successive steps or cycles of steps, differ in molecular mass, as in



**Charcoal:** A carbonaceous solid residue which is formed in the destructive distillation of wood. It has a very high surface area per unit weight which makes it especially useful as an absorber of various gases and vapours.

**Checkwork:** The multiple openings in a refractory wall which promotes turbulent mixing of the products of combustion.

**Chemical ionization:** The process in which primary ions, commonly formed by electron impact, react with neutral reagent gas molecules (e.g., by electron or proton transfer) to form reagent ions. The extent of fragmentation of the reagent ion can be controlled through the exothermicity of the transfer reaction. Commonly employed in chemical ionization mass spectrometry.

**Chemical potential: (GB)** The chemical potential  $\mu_B$  of a substance B in a mixture of substances B, C, . . ., is defined by

$$\mu_B = (\partial G / \partial n_B)_{T,p,n_C,\dots}$$

where  $G$  is the Gibbs energy of the mixture,  $T$  is the thermodynamic temperature,  $p$  is the pressure, and  $n_B$ ,  $n_C$ , . . ., are the amounts of the substances B, C, . . ., in the mixture.

**Chemisorption (or chemical adsorption):** Adsorption which results from chemical bond formation (strong interaction) between the adsorbent and the adsorbate in a monolayer on the surface. **GB:** Adsorption in which the forces involved are valence forces of the same kind as those operating in the formation of chemical compounds. If the molecule is adsorbed without fragmentation, the adsorption process is non-dissociative. Adsorption of carbon monoxide is frequently of this type.

**Chemiluminescent methods of detection (analysis):** Methods which utilize gas or liquid phase reactions between two molecules which produces a third molecule in an excited state. The wavelength distribution of the light emission from the excited molecule is characteristic of the species; in some circumstances this may be used to identify and to determine the concentration of one of the reacting species.

**Chemiluminescence analyser:** Instrument consisting of a reaction chamber with separate inlets for the sample and reagent gas, an optical filter, a photomultiplier and a signal processing device. The reactive gas is introduced in excess. The quantity of light produced is proportional to the sample flow rate and the concentration of the measured substance in the sample under specified temperature and pressure conditions. The filter limits the wavelength to the region of interest and helps to eliminate interferences.

**Chimney (stack):** A vertical flue for conducting cooled combustion products of a process to the atmosphere. This term also includes structures and opening of any kind from or through which smoke, grit, dust or fumes may be emitted.

**Chimney effect:** A vertical movement of a localized mass of air or other gases which occurs due to local temperature differences.

**Chimney height (stack height), effective:** A height used for the purposes of calculating the dispersion of emitted gases from a chimney, and which differs from the real chimney height by an amount which depends on such factors as the exit velocity, buoyancy effects and wind speed; it may also be affected by the local topography. It denotes the maximum height of the centre of a plume path above the level of the ground. The effective height may be above or below the actual chimney height, although the former case is most common.

**Chromatogram in chromatography:** A graphical presentation of detector signal against time, having a baseline and peaks.

**Chromatographic analysis (chromatography):** A method of separation of different chemical species based upon selective adsorption. Gas chromatography involves the separation of components (gases or vapours) in a gaseous stream (carrier gas) on a column of some suitable sorbent (stationary phase). Nonvolatile components are often separated by liquid chromatography where a solution of the components is separated

by partition between a liquid mobile phase and a "solid" stationary phase. In both cases, the stationary phase may either be a liquid (often chemically bonded to the support) in which the components selectively dissolve, or a solid on which they are selectively adsorbed. Ion chromatography and ion exchange chromatography are useful for the separation and analysis of the ions present in rain-water or cloud-water. **GB:** The stationary phase may be packed in a *column*, spread as a layer, or distributed as a film, etc.; in these definitions chromatographic bed is used as a general term to denote any of the different forms in which the stationary phase may be used. The mobile phase may be gaseous or liquid.

*Cloud:* An aerosol of the atmosphere which is dense enough to be perceptible to the eye. Usually refers to an assembly of water-droplet aerosols suspended in the atmosphere, although dust clouds are also recognized.

*Clouds, altostratus:* A grey, uniform, striated or fibrous sheet but without halo phenomena, and through which the sun is seen only as a diffuse, bright patch or not at all; usually at elevations 2 000-6 000 m; vertical velocities of 0.05-0.1 m s<sup>-1</sup>.

*Clouds, altocumulus:* A dappled layer of patch or cloud composed of flattened globules that may be arranged in groups, lines or waves collectively known as billows; 2 000-6 000 m; vertical velocities of 0.05-0.1 m s<sup>-1</sup>.

*Clouds, cumulus:* Detached, dense clouds with a dome-shaped upper surface with sharp-edged, rounded protuberances and a nearly horizontal base; 600-6 000 m or more; convective motion with rising, large bubbles of warm air with vertical speeds of 1-5 m s<sup>-1</sup>.

*Clouds, cumulonimbus:* Heavy masses of dense cloud whose cumuliform summits rise in the forms of towers, the upper parts having a fibrous texture and often spreading out into the shape of an anvil; these clouds generally produce showers of rain and sometimes of snow, hail or soft hail, and often develop into thunderstorms; up to 12 000 m; summits may be as cold as -50 °C; strong convective motions with vertical velocities of 3 to greater than 30 m s<sup>-1</sup>.

*Clouds, nimbostratus:* An amorphous, dark grey, rainy cloud layer reaching almost to the ground; 300-600 m; vertical velocities of 0.05-0.2 m s<sup>-1</sup>.

*Clouds, stratocumulus:* A layer of patches composed of laminae or globular masses arranged in groups, lines, or waves and having a soft, grey appearance; very often the rolls are so close together that their edges join and give the undersurface a wavy character; the process of formation (cumulogenesis) involves the spreading out of the tops of cumulus clouds, the latter having disappeared; <2 000 m; usually warmer than -5 °C; vertical velocities usually <0.1 m s<sup>-1</sup>.

*Clouds, stratus:* A uniform featureless layer of cloud resembling fog but not resting on the ground; when this very low layer is broken up into irregular shreds, it is designated as fractostratus; 300-600 m; widespread irregular stirring and lifting of the shallow layer of cool, damp air near the ground.

*Coagulation (flocculation):* Process of converting a finely divided or colloidal dispersed suspension of one substance (usually a solid) in a liquid into larger-size particles which do settle or precipitate under the influence of gravity. Aluminum sulfate or other salt which contains a trivalent or divalent metal ion is sometimes used for this purpose. For atmospheric aerosol, coagulation denotes the process by which particles grow due to the attachment of smaller, more mobile particles subject to Brownian motions. Aitken particles coagulate efficiently with larger particles. **GB:** When a sol is colloidal unstable (i.e. the rate of aggregation is not negligible) the formation of aggregates is called coagulation or flocculation.

*Coal desulfurization:* Processes by which sulfur compounds are removed from coal. Some of the sulfur content of coal is composed of iron pyrites (FeS) which has a density (about 5 g cm<sup>-3</sup>) very different from that of coal (1.25-1.45 g cm<sup>-3</sup>) and can be removed by mechanical cleaning processes. Many processes have been used to remove SO<sub>2</sub> from flue gases and others are under study: limestone scrubbing, catalytic oxidation, fluidized bed reactors, etc.

*COH, coefficient of haze:* One technique of measurement of the amount of filterable particulate matter suspended in air which has been used in the past depends upon drawing a measured sample of air (usually 1000 linear feet) through a paper or membrane filter. A measurement is made of the intensity of light transmitted through the dust spot formed relative to that transmitted through an identical clean filter. The dirtiness of the air is reported in terms of the COH unit. This relates to the quantity of particulate material which produces an optical density,  $\lg(I_0/I)$ , of 0.01 when measured by light transmission at 400 nm and relative to the transmission of an identical dust-free filter taken as 100%. Thus a filter which transmitted 50% relative

to the clean filter has an absorbance of 0.301 or 30.1 COH units. This is not a recommended measure of filterable particulate matter since the size, color and other properties of the aerosol and the air in which it is suspended affect the results.

**Collection efficiency:** A term which characterizes an entire sampling and sample pretreatment procedure, usually represented as a percentage of the original amount of the analyte which is left for measurement (signal formation) after having passed through this procedure. This term also applies to the efficiency of collection of an air pollutant by an arrestment plant. For particulates, the collection efficiency is size related.

**Collector:** A device for removing and retaining contaminants from air or other gases. Term which is often applied to cleaning devices in exhaust systems. Also used to designate a device for removing and retaining samples from media in different environmental compartments to be investigated. A collector is sometimes used to describe a *scavenger*. **GB:** A solid substance added to or formed within a solution to collect a micro- or macro-component.

**Collision number ( $z$ ) or collision frequency:** The number of collisions between two molecules  $A$  and  $B$  which occur per unit volume per unit time when both  $A$  and  $B$  are at a concentration of one molecule per unit volume;  $z_{AB} = \sigma_{AB}^2 \{8\pi kT(m_A + m_B)/m_A m_B\}^{1/2}$ , where  $\sigma_{AB} = (\sigma_A + \sigma_B)/2$ ,  $\sigma_A$  and  $\sigma_B$  are the diameters of  $A$  and  $B$ , respectively, assumed to be rigid spheres,  $k$  is the Boltzmann constant, and  $m_A$  and  $m_B$  are the masses of the molecules  $A$  and  $B$ , respectively. The number of  $A$ - $B$  collisions  $\text{cm}^{-3} \text{s}^{-1}$  is given by  $z[A][B]$ , where  $[A]$  and  $[B]$  are the concentration (molecules per unit volume) of  $A$  and  $B$ , respectively. Conventional units for  $z$  are number of collisions  $\text{cm}^{-3} \text{s}^{-1}$ . **GB:** In simple collision theory the rate coefficient of a bimolecular reaction between  $A$  and  $B$  is expressed as

$$k = p_{AB} z_{AB} e^{-E/RT}$$

where  $p_{AB}$ , the *steric factor*, allows for the fact that, even when the energy requirements are satisfied, all collisions are not effective in causing reaction.

**Colorimeter:** An instrument used for color measurement based on optical comparison with standard colors.

**Combustion chamber:** The region within which solids, vapours and gases from the primary chamber are burned and the some settling of fly ash takes place.

**Combustion gases:** Gases and vapours produced in furnaces, combustion chambers or in open burning.

**Complementary gas:** Generally the most abundant component (pure gas or gas mixture) which makes up the mixture intended for the calibration.

**Concentration, gas and liquid solutions:** This represents the quantity of matter (mol, g, molecules, or other) per unit of volume ( $\text{cm}^3$ , L,  $\text{m}^3$ , or other). The IUPAC **GB** designation of this quantity is the amount of substance concentration (with the SI base unit of  $\text{mol m}^{-3}$ , but practical units of  $\text{mol dm}^{-3}$  or  $\text{mol L}^{-1}$ ). For a gas phase species it is common to describe the concentration as the number of molecules of the particular species per  $\text{cm}^3$  of air; this unit is most common in gas phase kinetics and in calculations involving chemical changes in the atmosphere. The number concentration or number density, often employed in physics and in physical chemistry, describes the number of molecules per  $\text{cm}^3$ ; however in writing the units for this quantity, molecules are understood but omitted; only  $\text{cm}^{-3}$  is written. The most common method of describing concentration of a given solute in the liquid phase (such as cloud-water) is the amount of the compound or ion (in moles) present per litre of the solution. One mole of a given species is  $6.02213 \times 10^{23}$  (Avogadro constant) of these species. The *mixing ratio* is also employed as a measure of relative concentration. For a non-reactive gas, the mixing ratio does not change with altitude although the absolute concentration ( $\text{molecules cm}^{-3}$ ) decreases. Thus one part-per-million by volume (1 ppmv) is a concentration equivalent to one molecule of a given species present in one million molecules ( $10^6$ ) of air. Similarly one part-per-billion by volume (1 ppbv) represents a molecular ratio of one molecule for every  $10^9$  molecules of air; one part-per-trillion by volume (1 pptv) represents one molecule per  $10^{12}$  molecules of air. Concentrations of solids suspended in air are sometimes given in units of mass of the species per unit volume (e.g., micrograms per cubic meter of air). At times the mass fraction is used in contrast to the use of the volume, molecule, or mole fraction (e.g., ppmv); thus one part-per-million by mass (ppmm) is one unit of mass of a given species per million mass units of the mixture.

**Concentration, ground level:** The concentration of a chemical species, normally a pollutant, in air; usually measured at a specific height above the ground.

**Concentration, particle:** Commonly expressed in several ways: mass concentration (usually as  $\mu\text{g m}^{-3}$ ) or

number concentration (number of particles  $\text{cm}^{-3}$ ); modern instrumentation allows measurement of the number of particles as a function of size as well as the total number present in a given air volume. For atmospheric aerosols, this is a complex distribution for which diameters range from below 0.01 to above 100  $\mu\text{m}$ ; the particles making the highest contribution to the total number density are in the size range below 0.1  $\mu\text{m}$ , those contributing most to the total surface area are in the 0.1 to 1.0  $\mu\text{m}$  range, while those with the highest contribution to the volume or mass of the aerosol come from both the 0.1 to 1.0 and 1.0 to 100  $\mu\text{m}$  ranges.

*Condensation*: The physical process of converting a material from a gaseous or vapour phase to a liquid or solid phase; this commonly results when the temperature is lowered and/or the vapour pressure of the material is increased. The tendency exists for condensation to occur when the partial pressure of a given component of a gaseous mixture at a given temperature exceeds the vapour pressure of the liquid or solid form of that component at the given temperature.

*Condensation nuclei* (sometimes symbolized as CN): A particle, either liquid or solid, or an ion upon which condensation of water vapour (or other substances) begins in the atmosphere. Condensation nuclei are usually very small hygroscopic aerosols (0.001 to 0.1  $\mu\text{m}$  in diameter), but these are not as abundant as the smaller particles. The number of CN which are active (initiate condensation) in a given air mass may be a function of the relative humidity. Usually CN are counted as the active nuclei at about 300% relative humidity, while cloud condensation nuclei (CCN) are counted as the number of active nuclei at relative humidity less than or equal to 102%.

*Constituent* (with reference to an air sample): A component of the air sample for which a specified quantity is to be determined by measurement or analysis; see *air quality characteristic*.

*Contaminant, air*: A substance, gaseous material or aerosol, which is present in an air mass at levels greater than in clean air. An air contaminant has been added commonly by anthropogenic activity; see also *air pollutant*.

*Continuous air monitoring program (CAMP)*: In the United States the CAMP program represents a series of monitoring stations which were established near large cities for the continuous monitoring of gaseous pollutants,  $\text{SO}_2$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{CO}$ , hydrocarbons, and  $\text{O}_3$ .

*Control agencies*: Air pollution control agencies, established nationally or locally, which are designated to monitor and control air pollution in their designated areas through the enforcement of air pollution control legislation.

*Controlled atmosphere*: A synthetic gaseous sample of pure air which may contain carefully determined amounts of certain contaminants; this may be used as a standard for the calibration of analytical techniques, as a simulated environment for the study of biological responses, or for other purposes.

*Convection* (as applied to air motion): Vertical motion of the air induced by the expansion of the air heated by the earth's surface and its resulting buoyancy.

*Correlation coefficient*: A measure of the degree of interrelationship which exists between two measured quantities,  $x$  and  $y$ ; the correlation coefficient ( $r$ ) is defined by the following relation:

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

where  $x_i$  and  $y_i$  are the measured values in the  $i$ th experiment of  $n$  total experiments.  $\bar{x}$  and  $\bar{y}$  are the arithmetic means of  $x_i$  and  $y_i$ :

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad (\text{similar expression for } \bar{y})$$



The linear correlation coefficient indicates the degree to which two quantities are linearly related. If  $x = ay$  is followed then  $r = 1$ , and departures from this relationship decrease  $r$ ; if interpretations of data based on the linear correlation coefficient are to be made, one should consult a book on statistics.

**Cracking:** The thermal or catalytic decomposition of a compound such as a hydrocarbon into chemical species of smaller molecular weight.

**Critical temperature:** That temperature, characteristic of each gas, above which it is not possible to liquefy a given gas.

**Critical point:** The temperature and pressure at which the liquid and vapour intensive properties (density, heat capacity, etc.) become equal. It is the highest temperature (critical temperature) and pressure (critical pressure) at which both a gaseous and a liquid phase of a given compound can coexist.

**Cryogenic:** Term used to describe low temperature processes, apparatus, etc.; usually applied to systems operated at the temperature of liquid nitrogen, helium or other condensed gas which boils at a very low temperature (at atmospheric pressure); see *sampling, cryogenic*.

**Cumulative sample:** A sample collected over an extended period of time.

**Cupola:** A vertical shaft furnace used for melting metals; the melting of ores is accomplished in a blast furnace.

**Cut off** (as applied to aerosol sizes): The size of particles at which the retention efficiency of an instrument device drops below a specified value under defined conditions.

**Cyclone (collector):** A dust, grit, or droplet separator utilizing essentially the centrifugal force derived from the motion of the gas. The flow of gases containing suspended particles into the device is transformed into a confined vortex from which centrifugal forces tend to drive the suspended particles to the wall of the cyclone body. The agglomerated particles are subsequently removed from the cyclone by gravitational action.

**Cyclone (meteorology):** A large circulatory wind system around a region of low atmospheric pressure; rotation is counterclockwise (viewed from above) in the northern hemisphere and clockwise in the southern hemisphere.

**Dark reaction (darkness reaction):** A chemical reaction that does not require or depend on the presence of light. Contrasts with a *photochemical* reaction which is initiated by light absorption by one or more of the reactants.

**Dead time:** see *Analyser, dead time of*.

**Decay rate:** The rate at which a pollutant is removed from the atmosphere either by reaction with reactive transient species such as the HO-radical, O<sub>3</sub>, etc., by photodecomposition initiated by light absorption by the impurity, or by loss at the surface of aerosols, the earth, etc. The decay rate as applied to radioactive materials is related to the radioactive half-life ( $t_{1/2}$ ) of the particular isotopic species  $A$  and its concentration  $[A]_t$  at the given time ( $t$ ): Rate =  $[A]_t(\ln 2)/t_{1/2}$ .

**Deliquescence:** The process that occurs when the vapour pressure of the saturated aqueous solution of a substance is less than the vapour pressure of water in the ambient air. When water vapour is collected by the pure solid compound, a mixture of the solid and liquid, or an aqueous solution of the compound forms until the substance is dissolved and is in equilibrium with its environment; at this time the vapour pressure of water over the aqueous solution will equal the partial pressure of water in the atmosphere in contact with it. A crystalline salt aerosol particle will deliquesce in the atmosphere when the relative humidity surpasses a characteristic value, the so-called *deliquescence point*.

**Demister:** Apparatus made of wire mesh or glass fibre which is used to help remove acid mist as in the manufacture of sulfuric acid. Demisters are also components of wet arrestment plants.

**Density:** The mass per unit volume of a gas, liquid, or solid under specified conditions (temperature, pressure, etc.).

**Density, number:** The number of atoms, molecules or aerosol particles per unit volume of gas (commonly in units of molecules cm<sup>-3</sup>).

**Denuder system (tube or assembly):** An apparatus used to separate gases and aerosols (over a given diameter) which is based upon the difference in diffusion velocity between gases and aerosol particles. Usually a tube containing a selective internal wall coating which removes the gaseous compounds at the wall.

**Deodorizer:** Equipment for the removal of noxious gases and odors, which may consist of combustion, absorption, or adsorption units; see *emission control equipment*.

**Deposition:** Deposition is normally considered to be one of two types: *dry deposition* is the process by which aerosols and gases in the air are deposited on the surface of the earth (soil, water, rock, plants, etc.); this is termed "dry" deposition even when the receptor surface is moist. *Wet deposition* is that process which involves the transport of chemicals to the surface of the earth by water droplets or snow crystals which scavenge pollutants as they form and fall through the atmosphere.

**Deposition velocity:** The ratio of flux density (often given in units of  $\text{g cm}^{-2} \text{s}^{-1}$ ) of a substance at a sink surface to its concentration in the atmosphere (corresponding units of  $\text{g cm}^{-3}$ ). While the units of this ratio are clearly those of velocity (in this case  $\text{cm s}^{-1}$ ), the ratio is not a flow velocity in the normal sense of the word.

**Desorption:** The removal of a substance from a surface on which it has become absorbed. Desorption is accelerated by heating and exposure of the surface to a low pressure (or vacuum). **GB:** The converse of adsorption, i.e. the decrease in the amount of adsorbed substance.

**Desulfurization:** The process by which sulfur is removed from a material such as coal or oil. It may involve one of many techniques including elutriation, froth flotation, laundering, magnetic separation, chemical treatment, etc.

**Detection:** The process of establishing the presence of air pollutants by means of specific instrumentation and sampling.

**Detection limit, lower:** The minimum concentration of a compound in an air sample which can be determined by an analytical method with a given statistical probability. Usually the lower detection limit is defined as three-times the standard deviation of the noise of an analytical method under the assumption that its distribution is Gaussian. In this case a concentration can be detected with a probability of 99.7%. This is sometimes referred to as the *absolute detection limit (GB)*.

**Detection limit, relative: GB:** Smallest amount of material detectable (with 99.7% probability) in a matrix relative to the amount of material analysed - given in atomic, mole or weight fractions.

**Detection limit (threshold):** The minimum concentration of substance which produces an observable response.

**Detector:** An instrument or part of an instrument which indicates the presence of air quality characteristic by means of some specific spectroscopic or chemical property of the pollutant.

**Dew point:** That temperature at which water vapour present in the atmosphere is just sufficient to saturate it. When air is cooled below the dew point, the excess of water vapour appears as tiny droplets or crystals of ice depending on the temperature of the air mass. This term is also applicable to acid gases as in the problem of acid corrosion and acid smut formation.

**Diameter, equivalent:** The diameter of a spherical particle which will give identical geometric, optical, electrical or aerodynamic behavior to that of the particle (non-spherical) being examined; sometimes referred to as the Stokes diameter for particles in non-turbulent flows.

**Diffraction:** A modification which light (or electron, neutron beams, etc.) undergoes in passing by the edges of opaque bodies or through narrow slits or in being reflected from ruled surfaces (or crystalline materials). The light waves, owing to their wave-like nature appear to be deflected and produce fringes of parallel light and dark bands corresponding to regions of constructive reinforcement or destructive interference, respectively, of the waves.

**Diffraction analysis:** The application of diffraction techniques (X-rays, electrons, neutrons) which are sometimes used to identify the presence of certain solid aerosols and dust particles through the characteristic diffraction patterns which result from each unique crystal structure.

**Diffuser:** A porous plate or tube, commonly made of carborundum, alundum, or silica sand, through which air is forced and divided into minute bubbles for diffusion in liquids.

**Diffusion:** The spreading or scattering of a gaseous or liquid material. Eddy diffusion in the atmosphere is the process of transport of gases due to turbulent mixing in the presence of a composition gradient. Molecular diffusion is the net transport of molecules which results from their molecular motions alone in the absence of turbulent mixing; it occurs when the concentration gradient of a particular gas in a mixture differs from its equilibrium value. Eddy diffusion is the most important mixing process in the lower atmosphere, while molecular diffusion becomes significant at the lower pressures of the upper atmosphere.

**Diffusion battery:** An aerosol sizing instrument for particles with diameters below  $0.2\ \mu\text{m}$ . The fractionation is based on different diffusivities of the small particles and their deposition on the walls of the long parallel or circular channels, formed by equally spaced plates, bundles of small bore parallel tubes or sets of stainless wire screens.

**Diluent gas:** A gas of known quality introduced for analytical purposes so that it quantitatively lowers the concentration of the components of a gaseous sample; this may also be the *complimentary gas*.

**Dioxin:** Colloquial (short) name of a toxic by-product (and sometimes contaminant) of herbicides; the full name of this species is: 2,3,7,8-tetrachlorodibenzo[b,e][1,4]dioxin.

**Discomfort threshold:** The lowest value (e.g., concentration of an impurity, etc.) at which a sensation of discomfort is perceived; a measure which varies from person to person.

**Dispersion:** The dilution of a pollutant by spreading in the atmosphere due to diffusion or turbulent action (eddy diffusion).

**Dissociation energy:** see *bond dissociation energy*.

**Diurnal variation:** Indicates variations which follow a distinctive pattern which recurs with a daily cycle.

**Dobson unit:** Unit sometimes used in the description of the total ozone in a column of air overhead. It is given as the thickness (in units of  $10^{-3}\ \text{cm}$  or  $10^{-5}\ \text{m}$ ) of that layer which would be formed by the total ozone in a column reduced to the pressure of 760 Torr and temperature of  $0\ ^\circ\text{C}$ .

**Dosage:** As applied to an air pollutant in an exposure chamber, dosage is commonly defined as the concentration of the pollutant times the duration of exposure.

**Downwash:** As applied to the action of chimney gases, it is the downward motion of the chimney gases brought on by eddies which form in the lee of a chimney when the wind is blowing. It may result in bringing the flue gases to the ground prematurely.

**Droplet:** A small liquid particle. The size of droplets encountered in the atmosphere extends over a wide range; e.g., liquid aerosol solutions which make up the fine particle fraction of continental tropospheric aerosol are usually  $<2\ \mu\text{m}$  in diameter. Cloud water droplets usually have diameters in the range of 5 to 70  $\mu\text{m}$ , while rain droplets commonly have diameters ranging from 0.1 to 3 mm.

**Dry bulb temperature:** In psychrometry, the temperature of the gas measured by a dry bulb thermometer; see *psychrometry*.

**Drying agents:** Substances which remove water (liquid or gaseous).

**Dust:** Small, dry, solid particles projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or manmade processes such as crushing, grinding, milling, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping. Dust particles are usually in the size range from about 1 to 100  $\mu\text{m}$  in diameter, and they settle slowly under the influence of gravity.

**Dust collector:** A device for monitoring dust emissions. Also the equipment used to remove and collect dust from process exhaust gases; this may employ simply sedimentation (dustfall jars, coated slides, papers, etc.), inertial separation (cyclones, impactors, impingers, etc.), precipitation (thermal and electrostatic) or filtration.

**Dust fall:** Solid particles in the air which fall to the ground under the influence of gravity.

**Dynamic range of an analyser:** The ratio between the maximum usable indication and the minimum usable indication (detection limit). A distinction may be made between the linear dynamic range, where the response is directly proportional to concentration, and the dynamic range where the response may be non-linear, especially at higher concentrations.

**Eductor:** A liquid pump for mixing air with water which operates under a jet principle using the liquid under pressure as the operating medium.

**Eddy:** In turbulent fluid motion, a blob of the fluid that has some definitive character and moves in some way differently from the main flow.

**Eddy dispersion (diffusion):** The process by which substances are mixed in the atmosphere or in any fluid system due to eddy motion.

**Efflorescence:** The reverse of deliquescence: the drying of a salt solution when the vapour pressure of water in the saturated solution of a substance is greater than the partial pressure of water in the ambient air. Also refers to the loss of water of crystallization from a solid salt such as  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ .

**Effluent:** Any spent liquors or other waste material which are emitted by a source (waste from plating shops, pickling tanks, sewage treatment plants, chemical manufacturing plants, etc.).

**Einstein, unit:** 1 mole ( $6.02213 \times 10^{23}$ ) of quanta or photons of electromagnetic radiation; for monochromatic light of wavelength  $\lambda$ , a light beam of energy  $E$  ( $\text{J s}^{-1}$ ) striking a surface, will have  $E/(6.022 \times 10^{23} \times hc/\lambda)$  Einstein striking per sec;  $h$  is the Planck constant ( $6.626 \times 10^{-34}$  J s) and  $c$  is the velocity of light ( $2.998 \times 10^8$  m  $\text{s}^{-1}$ ).

**Electrochemical methods of detection (analysis):** Methods in which either current or potential is measured during an electrochemical reaction. The gas or liquid containing the trace impurity to be analysed is sent through an electrochemical cell containing a liquid or solid electrolyte and in which an electrochemical reaction specific to the impurity takes place.

**Electrochemical methods, amperometric detection:** The current is proportional to the concentration of the species generating the current.

**Electrochemical methods, coulometric detection:** The current is directly proportional to the flow rate of the substance involved in the electrochemical reaction, and the amount of charge which flows is proportional to the amount of substances taking part in the reaction.

**Electrochemical methods, potentiometric detection:** The potential of a cell is related to the concentration (activity) of a reactant which is a component of the cell fluid.

**Electron charge:** The negative electric charge which appears on the electron or univalent ions [ $1.602 \times 10^{-19}$  coulombs or  $4.803 \times 10^{-10}$  electrostatic units (esu)].

**Electrostatic filter:** Filters for which an electrostatic charge is applied to the filter element. A fibrous filter material is often pleated in between V-shaped supports consisting of electrostatically charged, metal rods which are insulated from the supporting frame.

**Electrostatic precipitator:** A device which separates particles from a gas stream by passing the carrier gas between pairs of electrodes across which a unidirectional, high-voltage potential is placed. The particles are charged before passing through the field and migrate to an oppositely charged electrode. These devices are very efficient collectors of small particles, and their use in removing particles from power plant plumes and in other industrial applications is widespread.

**Eluate: GB:** The effluent from a chromatographic bed emerging when elution is carried out.

**Elute:** To remove sorbed materials from a sorbent by means of a fluid called the *eluent*. **GB:** To chromatograph by elution chromatography. This term is preferred to the term *develop*, which has been used in paper chromatography and in thin-layer chromatography. The process of elution may continue until the components have left the chromatographic bed.

**Elutriation:** The process of separating the lighter particles of a powder from the heavier ones by means of an upward directed stream of fluid (gas or liquid).

**Emission:** The total rate at which a solid, liquid, or gaseous pollutant is emitted into the atmosphere from a given source; usually expressed as mass per unit time. *Primary emissions* are those substances which are emitted directly to the atmosphere (e.g., NO, SO<sub>2</sub>, etc.), while *secondary emissions* are formed from the primary emissions through thermal or photochemical reactions (e.g., ozone, aldehydes, ketones, sulfuric acid, nitric acid, etc.). The point or area from which the discharge takes place is called the *source*; the area in

which the emission or its transformed products (e.g., in the case of aerosols, acidic deposition, etc.) may be deposited is called the *receptor area* or *sink*. *Emission* may be applied to noise, heat, etc., as well as pollutants.

*Emission control equipment*: Air pollution control equipment which either converts the pollutant chemically to a non-polluting substance or collects the pollutant by some means including gravity settling chambers, inertial separators, cyclonic separators, filters, electrical precipitators, scrubbers, (spray towers, jet scrubbers, Venturi scrubbers, inertial scrubbers, mechanical scrubbers and packed scrubbers). Certain gases and odoriferous compounds are controlled by combustion, absorption (spray chambers, mechanical contactors, bubble cap or sieve plate contactors, and packed towers), and adsorption units (packed beds or fluidized beds).

*Emission flux*: The emission per unit area of the appropriate surface of an emitting source.

*Emission inventory*: A systematic collection of information concerning the air pollution emissions in a given area. Usually the types of sources (power plants, refineries, etc.) and the height at which the discharge takes place as well as the source contribution (composition and rate of discharge) are summarized. The variation of these emissions with time of day, and month of the year are desired information in inventories as well.

*Emission source*: Several types of emission sources exist: *Point* sources of emission include: power plants, incinerators, refineries, steel mills, chemical plants, etc. Often the emissions for these sources are released from elevated stacks. *Mobile* sources of emission include: automobiles, trucks, buses, ships, airplanes, etc.

*Enforcement*: The act of preventing the discharge into the atmosphere from any source operating without a permit or in violation of the terms of a permit or rules, regulations, or orders of an pollution control agency.

*Enthalpy*: The enthalpy ( $H$ ) of a system is defined by the equation

$$H = U + pV$$

where  $U$  is the internal energy,  $p$  is the pressure, and  $V$  is the volume of the system.

*Entrainment*: The act of forming a mist or fog droplets of a liquid carried off by the vapours of a boiling liquid or from a liquid through which bubbles of gas or vapour are passing rapidly.

*Entropy*: The entropy ( $S$ ) of a system is defined by the equation

$$dS \geq dq/T$$

where  $dq$  is the infinitesimal heat absorbed by the system which is at the thermodynamic temperature,  $T$ .

*Equilibrium*: A dynamic or static state of balance between opposing forces or actions. A dynamic equilibrium exists between two different phases of a given pure compound (liquid-gas, gas-solid, solid-liquid) when there is no net change in the amount of either phase when the two remain in contact; this occurs at a given temperature when the vapour pressures of each of the two phases of the compound are equal. A dynamic equilibrium exists in a reversible chemical reaction system at a given temperature and pressure, when the reactions generating and destroying each reactant and product continue to occur, but there is no net change in the amounts of the reactants or products present.

*Equilibrium constant*: The constant (at a given temperature) that relates the concentrations of reactants and products in a reversible chemical reaction at equilibrium. Consider an equilibrium established in a reversible chemical system containing molecules of  $A$ ,  $B$ ,  $C$ , and  $D$ , which react by the stoichiometry:  $aA + bB = cC + dD$  (where  $a$ ,  $b$ ,  $c$ , and  $d$  are the coefficients of the respective reactants and products in the balanced chemical equation describing the change). When the system is at equilibrium, the rates of the forward and reverse reactions become equal, and no further change in reactant and product concentrations occurs at a fixed temperature and pressure. At this time the equilibrium constant,  $K_p$ , is given by:  $K_p = [P_C]^c [P_D]^d / [P_A]^a [P_B]^b$  where  $p_X$  represents the pressure of the  $X$  species at equilibrium. Pressures must be replaced by fugacities for systems at high pressures. Equilibrium constants based upon fugacities are symbolized by  $K_f$ . For solution phase reactions, concentration units (or activities for concentrated solutions) are employed for the reactant and products, and a similar equilibrium expression can be written:  $K_c = [C]^c [D]^d / [A]^a [B]^b$ . When fugacities or activities are employed, the equilibrium expressions hold accurately regardless of the starting pressures or concentrations of the reactants and products. For systems at reasonably low pressures (near one atmosphere) or low concentrations, the  $K_p$  and  $K_c$  expressions given above hold reasonably well.

*Error, random:* The random fluctuations observed in the output from a measurement apparatus or method when the input to the instrument or method is held constant.

*Error, systematic:* Errors in a measurement which stay more or less constant and which may be attributed to the particular design of the measurement. Such errors may in principle be accounted for and eliminated, in contrast to random errors, which may not be eliminated.

*Evaporation:* The physical process by which a liquid substance is converted to a gas or vapour. This may occur at or below the normal boiling point of the liquid (the temperature at which a liquid boils at 1 atmosphere pressure), and the process is endothermic.

*Excitance, radiant, spectral:* The derivative of the incident radiant power with respect to the projected area of a specified emitting surface ( $\text{W cm}^{-2}$ ). With the adjective *spectral*, differentiation with respect to wavelength is also implied ( $\text{W cm}^{-2} \text{nm}^{-1}$ ). Irradiance and excitance are similar but refer to energy *arriving at* versus *leaving from* a surface, respectively.

*Explosivity limits (or explosion limits); flammable limits:* The concentration limits, usually of a substance in air, between which combustion will be self-sustaining.

*Exposure:* Subjecting a person, animal, plant, or material to an environment containing a significant concentration of an air pollutant.

*Exposure chamber:* In environmental studies, this is a suitable room or chamber in which the atmosphere may be controlled (relative humidity, pollutant concentrations, temperature, light intensity, etc.) and in which exposure to animals, plants, or materials can be made. The exposure of humans to small concentrations of any toxic or seemingly non-toxic chemical in chambers is a very hazardous practice which should be avoided; errors in the controls of the contaminant concentration and allergic reactions, etc., can occur with risk to life.

*Extinction coefficient:* see *absorption coefficient, scattering cross section*.

*Eye irritation:* Experienced by many persons upon exposure to some compounds (often lachrymators) in polluted air:  $\text{SO}_2$ ,  $\text{SO}_3$ , HCl, formic acid, peroxyacetyl nitrate (PAN), formaldehyde, acrylaldehyde, etc.

*Fabric filter:* See *Bag filter*.

*Fallout:* A measurement of air contamination consisting of the mass rate at which solid particles deposit from the atmosphere. See *Dust fall*.

*Fanning:* In blast furnace operation, the idling period between the blowing periods when the blast pressure is reduced to a minimum. This also applies to plume behaviour under inversion conditions; see *gas plume*.

*Filter:* A porous material on which solid particles present in air or other fluid which flows through it are largely caught and retained. Filters are made with a variety of materials: cellulose and derivatives, glass fibre, ceramic, synthetic plastics and fibres. Filters may be naturally porous or be made so by mechanical or other means. Membrane/ceramic filters are prepared with highly controlled pore size in a sheet of suitable material such as polyfluoroethylene, polycarbonate, or cellulose esters. Nylon mesh is sometimes used for reinforcement. The pores constitute 80-85% of the filter volume commonly, and several pore sizes are available for air sampling (0.45 to 0.8  $\mu\text{m}$  are commonly employed).

*Filtration:* The process of segregation of phases; e.g., the separation of suspended solids from a liquid or gas, usually by forcing a carrier gas or liquid through a porous medium.

*Flame photometry:* The use of emission spectroscopy in the ultraviolet and visible regions to identify and estimate the amounts of various elements which are excited in a flame, an arc or high voltage spark.

*Flare, solar:* A bright eruption of energy from the sun's chromosphere.

*Flash point:* The lowest temperature at which a substance, e.g., fuel oil, will give off a vapour that will flash or burn momentarily when ignited.

*Flocculation:* A process of contact and adhesion whereby the particles of a dispersion form larger-size clusters. Synonymous with *agglomeration* and *coagulation*.

*Floccule:* A small loosely aggregated mass of material suspended in or precipitated from a liquid; a cluster

of particles.

*Flow analysis:* The determination of selected analytes by injection of discrete test portion plugs into a liquid flow without or with segmentation by gas or nonmiscible liquids. Determination is accomplished by suitable detectors (e.g., UV, visible; fluorescence, electrochemical) either directly or following on-line chemical reactions(s) and/or extraction.

*Flowmeter:* An instrument for measuring the rate of flow of a fluid moving through a tube, pipe or duct system. The instrument is calibrated to furnish volume or mass rate of flow. Several types of flowmeters are in use: a) *Variable area flowmeter:* A flowmeter consisting of a tapered tube and a float. The gas enters at the bottom of the tube. The inner diameter of the tube increases from the bottom to the top, and the float is supported in the tube at a height which is a function of the rate of flow and the nature of the gas in the tube; this is sometimes referred to as a "rotameter" which is derived from a trademark. b) *Soap film flowmeter:* A flowmeter in which a soap film is generated on a cross section of a graduated tube (sometimes a calibrated buret is employed) in which the gas to be measured passes. The film moves along the tube at the same rate as the gas flow. The measured time required for the film to sweep through a measured volume can be used to calculate the gas flow rate. This is often employed in gas chromatography work. c) *Critical orifice flowmeter:* A device consisting of a plate having an orifice of small diameter and placed in a gas stream such that the total flow passing through the orifice has a velocity at least equal to the sonic velocity. A pressure measuring device is attached upstream of the orifice. The flow is proportional to the upstream pressure and independent from the downstream pressure. d) *Spirometer:* An absolute flow measuring device consisting of two cylinders each sealed at one end and having slightly different diameters. The smaller is inverted into the larger which is filled with a confining liquid. The inverted cylinder is suspended with counterweights so that it moves freely within the larger cylinder. Gas may either be displaced from the smaller cylinder or admitted to it. The dimensions of the smaller cylinder must be known. The rate of rise or fall of the inverted cylinder can be used to calculate the rate of flow of gas either into or out of the spirometer. The device is used principally for calibrating other devices. Other types of flow meters also are in wide use today (e.g., the Hastings-type mass flowmeter).

*Flow rate:* The volume or mass flow per unit time.

*Flow regulator:* A device used in sampling to maintain constant airflow for a given period of time.

*Flue:* A passage for the conduction of combustion gases in an incinerator; synonymous with chimney. The term also applies to structures and openings of any kind used to transport gases in operations other than incineration.

*Flue gas:* Waste gas from the combustion process.

*Flue gas scrubber:* Equipment for removing fly ash and other objectionable materials from the products of combustion by means of sprays or wet baffles.

*Fluid flow:* The movement of air or other fluid in the open or in a duct, pipe, or passage. The flow can be of several types: a) *Uniform flow* is steady in time, or the same at all points in space; b) *Steady flow* is that for which the velocity at a point fixed with respect to a fixed system of coordinates is independent of time; c) *Rotational flow* has appreciable vorticity and cannot be described mathematically by a velocity potential function; d) *Turbulent flow* is that in which the fluid velocity at a fixed point fluctuates with time in a nearly random fashion; e) *Laminar flow* is that in which the mass of fluid may be considered separate laminae (sheets) with simple shear existing at the surface of contact of laminae if there is any difference in mean speed of the separate laminae; f) *Streamline flow* is that in which fluid particles move along the streamlines; this motion is characteristic of viscous flow at low Reynolds numbers.

*Fluorimeter:* An instrument used to measure the intensity and the wavelength distribution of the light emitted as fluorescence from a molecule excited at a specific wavelength or wavelengths within the absorption band of a particular compound. Characteristic fluorescence bands may be used to identify specific pollutants such as the polynuclear aromatic hydrocarbons. *Excitation spectra* of impurities can be observed by scanning the wavelength of the excitation light which is incident on the sample over a range of wavelengths and observing the relative intensity of the fluorescence emitted at a given wavelength. These spectra are also characteristic of the impurity.

*Flux:* The number or mass of particles or molecules which pass through a given unit area of surface per unit time. *Net vertical flux* of a species is the difference between the downward and upward flux of that species.

*Flux density, photon:* **GB:** At a given point in space, the number of photons incident in a time interval on a suitably small sphere centred at that point, divided by the cross-sectional area of that sphere and by the time interval.

See also *actinic flux*.

*Fly ash:* Finely divided particles of ash entrained in flue gases resulting from the combustion of fuel.

*Fly ash collector:* Equipment to remove fly ash from the products of combustion.

*Fog:* A general term applied to a suspension of droplets in a gas. In meteorology, it refers to a suspension of water droplets resulting in a visibility of less than 1 km. **GB:** An *aerosol* of liquid particles, in particular a low cloud.

*Fog horizon:* The top of a fog layer which is confined by a low-level temperature inversion and gives the appearance of the horizon (which it actually obscures) when viewed from above, against the sky.

*Fossil fuels:* Fuels such as coal, oil, and natural gas which have formed over many years through the decomposition of deposited vegetation which was under extreme pressure of an overburden of earth.

*Fragment ion in mass spectrometry:* An ion obtained when a molecule in the gaseous mixture under analysis is split into fragments during the ionization process (impact with the ionizing electron beam). **GB:** An ion produced by the loss of one or more fragments from a parent molecular ion.

*Free Radical:* See *Radical*.

*Freezing out:* Term used in combustion for the analysis of incinerator flue gas components (largely the organic fraction) in which a series of traps at progressively lower temperatures are employed. In more general use, the term implies the removal of a condensable gas or liquid by condensation in a trap at low temperatures.

*Frequency distribution:* If the range of observed measurement values is subdivided into a regular sequence of smaller intervals, this distribution is a plot of the frequency of occurrence of values falling into each interval.

*Fugacity:* Fugacity is a thermodynamic quantity related to the Gibbs energy (older terminology of Gibbs free energy not recommended) of a gaseous molecule. For pressures of gases near 1 atm, the partial pressure of a gas and the fugacity have nearly the same values. **GB:** The fugacity  $f_B^*$  of a pure gaseous substance B is a quantity with the same dimensions as pressure, defined in terms of the absolute activity  $\lambda_B^*$  of the pure gaseous substance B by

$$f_B^* = \lambda_B^* \lim_{p \rightarrow 0} (p/\lambda_B^*) \quad (T \text{ constant})$$

or in terms of chemical potential  $\mu_B$  by

$$RT \ln f_B^* = \mu_B^* + \lim_{p \rightarrow 0} (RT \ln p - \mu_B^*) \quad (T \text{ constant})$$

where  $p$  is the pressure of the gas and  $T$  is the thermodynamic temperature. The fugacity  $f_B$  of the substance B in a gaseous mixture containing mole fractions  $y_B, y_C, \dots$ , of the substances B, C,  $\dots$ , is a quantity with the same dimensions as pressure, defined in terms of the absolute activity  $\lambda_B$  of the substance B in the gaseous mixture by

$$f_B = \lambda_B \lim_{p \rightarrow 0} (y_B p / \lambda_B) \quad (T \text{ constant})$$

or in terms of chemical potential  $\mu_B$  by

$$RT \ln f_B = \mu_B + \lim_{p \rightarrow 0} (RT \ln y_B p - \mu_B)$$

where  $p$  is the pressure of the gas and  $T$  is the thermodynamic temperature.

*Fume:* Fine solid particles (aerosol), predominantly less than 1  $\mu\text{m}$  in diameter, which results from the



condensation of vapour from some types of chemical reaction. Usually this is formed from the gaseous state generally after volatilization from melted substances and often accompanied by chemical reactions such as oxidation.

*Fumes*: In popular usage, a term often taken to mean airborne effluents, unpleasant and malodorous, which might arise from chemical processes; see *smoke*.

*Fumigation*: An atmospheric phenomenon in which pollution, retained by an inversion layer near its level of emission, is brought rapidly to ground level as the inversion breaks up. This term also applies to the exposure of material (e.g., grain) to chemicals to kill insects, etc.

*Gas analysis installation*: Assembly for the purpose of determining one or more components in a gaseous mixture. It generally comprises the following elements: sample probe, region of primary treatment of the gases, region of secondary treatment of gases, points for venting to the atmosphere and for calibration sample injection, transfer line, and the analytical unit.

*Gas black*: (also carbon black, channel black, furnace black) Finely divided carbon (graphite) produced by incomplete combustion or thermal decomposition of natural gas.

*Gas chromatography*: A method of separating the components of a gas mixture. The sample is passed, in a stream of carrier gas, through a column which has different retention properties relative to the components of interest. Different components pass through the column at different rates and are detected as they elute from the column. **GB**: Comprises all chromatographic methods in which the moving phase is a gas. The word *chromatography* itself implies that a stationary phase is present in addition to the moving phase. See also chromatographic analysis.

*Gas chromatography, detector in*: Generally a device which provides an analogue output proportional to the instantaneous concentration of the substance or its instantaneous eluting rate in the carrier gas.

*Gas chromatography, electrochemical detector*: An electrochemical cell which responds to certain substances in the carrier gas eluting from the column. The electrochemical process may be an oxidation, reduction or a change in conductivity.

*Gas chromatography, electron capture detector*: A small radioactive source containing  $^3\text{H}$  or  $^{63}\text{Ni}$  ionizes the molecules of the carrier gas (nitrogen or argon-methane), and a potential difference creates a small current. This current is reduced when an electronegative substance (such as a halocarbon) is introduced. The reduction in current is a measure of the concentration of the electronegative substance. The detection limit (threshold) varies greatly according to the substances to be analysed and can reach a mixing ratio of  $10^{-12}$ . The linear dynamic range may be  $10^4$  but the maximum measuring value generally lies below 1 ppmv.

*Gas chromatography, flame ionization detector*: The gases emerging from the column are fed into a hydrogen flame across which an electrical potential is placed. Certain molecules ionize easily in the flame and the current produced is proportional to the instantaneous flow rate of the eluted component. The detector is relatively insensitive to inorganic molecules and is most used for organic compounds. Concentrations below 1 ppmv are easily detected. The linear dynamic range is between  $10^3$  and  $10^5$ .

*Gas chromatography, flame photometric detector*: The eluent from the column is fed into a hydrogen-rich flame and produces light emission. Optical filters are used to select the wavelength range of the emission which is characteristic of specific atoms (usually sulfur or phosphorous). The detector is very specific, depending on the choice of optical filters. It can detect the S- and P-containing compounds down to  $10^{-3}$  ppmv, but the detector is nonlinear.

*Gas chromatography, helium ionization detector*: A weak beta source and a high potential raise the helium atom of the carrier gas to a metastable state. All other substances having an ionization potential lower than 18 eV are ionized, and the current that results is used to measure the components. The detector is usually employed to measure inorganic compounds at concentrations between 0.1 and 10 ppmv. It has a linear range of about  $10^2$  but is somewhat unstable and requires great care to ensure the helium purity and to eliminate all leaks in the system.

*Gas chromatography, mass spectrometric detector*: A mass spectrometer can be used as a detector and gives qualitative and quantitative data on the various eluted substances. The mass spectrum of the eluted compounds provide evidence beyond the elution time as to the chemical nature of the species.

*Gas chromatography, photoionization detector*: Radiation from an ultraviolet lamp ionizes certain species in

the carrier gas. A potential difference is applied and the resulting ionization current is detected. The detector is only useful for substances with ionization potentials below about 11 eV. This makes it quite useful for detecting one component of a combined eluent when the other component, for instance nitrogen, has a high ionization potential. The detector has a small linear dynamic range and is capable of detecting substances below 1 ppmv.

*Gas chromatography, thermal conductivity detector:* In general, two cells arranged in a bridge configuration detect the change in thermal conductivity of the gas at the output of the column. This detector is sensitive to any substance with thermal conductivity different from that of the carrier gas. The lowest detectable limit is between 0.5 and 100 ppmv. The linear dynamic range is of the order of  $10^3$ . This type of detector is often used for measuring components at relatively high concentrations.

*Gas chromatography, ultrasonic detector:* Sound is generated in a reference cell and a measuring cell. An eluted component passing through the measuring cell changes the velocity of sound in the cell. This change is detected by a phase shift of acoustic signals between the two cells. This detector is usually employed for inorganic gases in the region where thermal conductivity detectors are not sufficiently sensitive. The detection threshold is of the order of 0.1 ppmv. The linear dynamic range is of the order of  $10^3$ .

*Gaseous diffusion separator:* Instrumentation to separate a gas mixture into its components by means of differences in the diffusion rates of the component molecules. This method has been used in separation of various isotopes of uranium (by means of  $UF_6$ ) and hydrogen ( $H_2O$ , HDO,  $D_2O$ , HTO, etc.)

*Gas-liquid chromatography; partition chromatography: (GB)* Comprises all gas-chromatographic methods in which the stationary phase is a liquid distributed on a solid support. Separation is achieved by partition of the components of a sample between the phases. In this and in gas-solid chromatography the first word specifies the mobile phase and the second word the stationary phase. Liquid stationary phases are supported on solids, but the solid support affects the chromatographic process. For classification, the term relating to the predominant effect is chosen.

*Gas plume:* The stack effluent which may assume various geometrical forms and concentration distributions which are dependent on the degree of turbulence: a) *Looping plumes* are formed under conditions of high convective turbulence which may result from the intense solar heating of the earth's surface or from mechanical turbulence induced from nearby hills upwind of the stack; b) *Coning plumes* which are reasonably symmetrical, occur under more nearly neutral thermal conditions when both convective and mechanical turbulence are relatively low; c) *Fanning plumes* occur under stable conditions, often at night, when the vertical component of the mechanical turbulence is suppressed more than the horizontal component so that the horizontal plume width is greater than its vertical thickness; d) *Fumigating plume* is caused by unstable air below and a stable layer above which results in a downward dispersion of gases which is greater than that seen under stable conditions; often occurs in the morning following a night of marked stability as the sun heats the ground to create the instability from the ground upward; e) *Lifting plume* is caused by conditions inverse to those causing fumigation and results in a greater diffusion upward; the meteorology of late afternoon and early evening often favors this condition.

*Gaussian distribution function:* A distribution function,  $f(x)$ , defined by the following equation:

$$f(x) = [\sigma(2\pi)^{1/2}]^{-1} \exp[-(x - \bar{x})^2/2\sigma^2]$$

where  $\bar{x}$  is the arithmetic mean of  $x$  and  $\sigma$  is the standard deviation.

*Gibbs energy:* The Gibbs energy ( $G$ ) of a system is defined by the equation:

$$G = H - TS$$

where  $H$  is the enthalpy,  $T$  is the thermodynamic temperature, and  $S$  is the entropy of the system.

*Gradient:* A differential ratio; the change in a quantity such as the mixing ratio of an impurity in air, the temperature of the air, etc., with height or distance.

*Gravimetric methods:* A determination by weight; e.g., in the older method of  $Cl^-$  ion determination, a weighed amount of sample is dissolved in water,  $AgNO_3$  solution added,  $AgCl$  is precipitated, dried and weighed. From the known mass fraction of silver in  $AgCl$ , the weights of the initial sample and that of the  $AgCl$  precipitated, the percentage of chlorine in the sample can be calculated readily.

*Greenhouse effect:* Heating effect produced by certain gases (e.g.,  $CO_2$ ,  $O_3$ , etc.), which by virtue of their

characteristic infrared absorption, lower the earth to space transmission of long wavelength radiation but allow transmission of shorter wavelength radiation inward from the sun to the earth.

**Grit:** Airborne solid particles in the atmosphere which are of natural or manmade origin and which remain in suspension for some time; in the United Kingdom the size of the grit particles is defined as greater than 75  $\mu\text{m}$  in diameter (retained on a 200 mesh British Standard sieve).

**Ground level inversion:** The inversion of the normal temperature gradient in the atmosphere; the temperature of the air increases with increasing height of the air above the ground. This leads to poor mixing of gases released below the inversion.

**Gustiness:** Intensity of turbulence; the ratio of the root mean square of wind velocity fluctuations to the mean wind velocity.

**Half-life:** see *lifetime*.

**Halocarbons/halogenated hydrocarbons:** The substitution of one or more of the hydrogen atoms in an alkane or alkene by halogen atoms (chlorine, fluorine, bromine, or iodine) generates useful compounds for use in many fields. Those hydrocarbons in which all of the hydrogen atoms are replaced by halogens are designated as halocarbons. These have been used extensively in refrigeration, "aerosol" spray cans, manufacture of insulation, etc. Two common anthropogenic halocarbons are: trichlorofluoromethane ( $\text{CCl}_3\text{F}$ ), designated by the Dupont Company as Freon-11; dichlorodifluoromethane ( $\text{CCl}_2\text{F}_2$ ), designated by the DuPont Company as Freon-12. Several other halocarbons and alkyl halides are used commercially and also appear as trace gases in the atmosphere: tetrachloromethane (or carbon tetrachloride,  $\text{CCl}_4$ ), 1,1,1-trichloroethane (or methyl chloroform,  $\text{CCl}_3\text{CH}_3$ ), trichloroethene (or trichloroethylene,  $\text{CCl}_2=\text{CCHCl}$ ), tetrachloroethene (or perchloroethylene,  $\text{CCl}_2=\text{CCl}_2$ ), dichloromethane ( $\text{CH}_2\text{Cl}_2$ ). The lifetimes of many of the chlorofluorocarbons (e.g.,  $\text{CClF}_3$ ,  $\text{CCl}_2\text{F}_2$ , etc.) are very long in the troposphere, and the major destruction of these species occurs in the stratosphere where photodecomposition of the halocarbons produces Cl-atoms which are involved in pathways to stratospheric ozone destruction. International agreements are anticipated to control the manufacture and release of the very long-lived halocarbons, and replacement of these by species which are destroyed within the troposphere is anticipated.

**Haze:** A state of reduced visibility (1-2 km) resulting from the increased light scatter due to the presence of fine dust or aerosol particles ( $\text{H}_2\text{SO}_4$ ,  $\text{NH}_4\text{HSO}_4$ , products of the ozone-terpene reactions, etc.).

**Haze horizon:** The top of a haze layer which is confined by a low-level temperature inversion so that it gives the appearance of the horizon which it may obscure.

**Henry's law:** An expression describing the equilibrium partitioning of a gas or vapour between two volumes of a gas and liquid in contact with each other. For dilute solutions of gases which do not react to form dissociated (or ionized) species in solution, the equilibrium concentration of a gas  $X$ ,  $[X]$ , dissolved in a liquid is proportional to the partial pressure of this gas,  $p_x$ :  $[X] = H_x p_x$ . Common practice in atmospheric chemistry is the use of concentration in  $\text{mol L}^{-1}$  and pressure of gas in atm with resulting units of  $\text{mol L}^{-1} \text{atm}^{-1}$  of the Henry's law constant,  $H_x$ . The simple form of this law is suitable to describe the solubility in water of many gaseous species which are of atmospheric interest ( $\text{O}_3$ ,  $\text{O}_2$ ,  $\text{H}_2\text{O}_2$ , etc.), but a modified form of Henry's law must be used to describe the solubility of gases which react with water (e.g.,  $\text{SO}_2$ ).

**HO-Radical (also OH-Radical):** The hydroxyl radical. A reactive radical which is a very important intermediate in the chemistry of the atmosphere. It is a neutral fragment of the  $\text{H}_2\text{O}$  molecule which is formed largely through the two reaction pathways: a) photolysis of ozone forming  $\text{O}(^1\text{D})$  atoms which react with  $\text{H}_2\text{O}$ ,  $\text{O}(^1\text{D}) + \text{H}_2\text{O} \rightarrow 2\text{HO}$ ; b) the reaction of  $\text{HO}_2$  radicals with  $\text{NO}$ ,  $\text{HO}_2 + \text{NO} \rightarrow \text{HO} + \text{NO}_2$ . The HO-radical reacts readily with most hydrocarbons (RH) to generate alkylperoxyl or arylperoxyl radicals ( $\text{RO}_2$ ),  $\text{HO} + \text{RH} \rightarrow \text{R} + \text{H}_2\text{O}$ ;  $\text{R} + \text{O}_2 \rightarrow \text{RO}_2$ ; aldehydes (RCHO) react to form acylperoxy radicals,  $\text{RCHO} + \text{HO} \rightarrow \text{RCO} + \text{H}_2\text{O}$ ;  $\text{RCO} + \text{O}_2 \rightarrow \text{RCOO}_2$ . These peroxy radicals react in  $\text{NO}_x$ -containing atmospheres to oxidize  $\text{NO}$  to  $\text{NO}_2$ ,  $\text{RO}_2 (\text{RCOO}_2) + \text{NO} \rightarrow \text{RO} (\text{RCO}_2) + \text{NO}_2$ . The RO radical usually reacts with  $\text{O}_2$  to form an  $\text{HO}_2$ -radical plus a carbonyl compound.  $\text{RCO}_2$  radicals decompose readily,  $\text{RCO}_2 \rightarrow \text{R} + \text{CO}_2$ . This set of reactions constitutes a chain reaction involving HO- and  $\text{HO}_2$ -radicals which results in the oxidation of many molecules of  $\text{NO}$  to  $\text{NO}_2$  for each HO-radical generated initially. The chain is terminated largely by reaction of HO-radicals with  $\text{NO}_2$  or by the occurrence of  $\text{HO}_2$ - $\text{HO}_2$  and  $\text{HO}_2$ - $\text{RO}_2$  reactions:  $\text{HO} + \text{NO}_2 \rightarrow \text{HNO}_3$ ;  $2\text{HO}_2 \rightarrow \text{H}_2\text{O}_2 + \text{O}_2$ ;  $\text{HO}_2 + \text{RO}_2 \rightarrow \text{RO}_2\text{H} + \text{O}_2$ . The reaction sequence outlined is responsible for the development of photochemical smog through the generation of  $\text{NO}_2$  and hence  $\text{O}_3$  through its photodissociation reaction.

**HO<sub>2</sub>-Radical:** The hydroperoxyl radical. A reactive radical which, together with the HO-radical, constitute

the elements of a radical chain reaction which results in the oxidation of NO to NO<sub>2</sub> and ultimately O<sub>3</sub> formation in the troposphere; see *HO-radical*. The HO<sub>2</sub>-radical is also a major source of H<sub>2</sub>O<sub>2</sub> in the troposphere through the reaction, 2HO<sub>2</sub> → H<sub>2</sub>O<sub>2</sub> + O<sub>2</sub>.

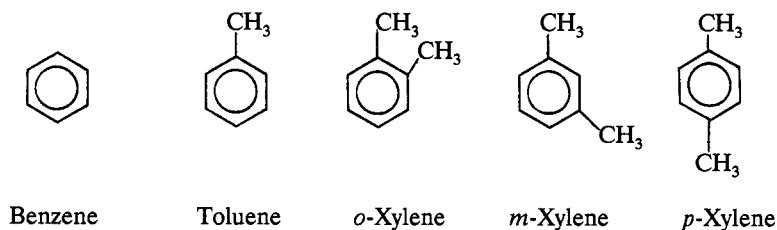
*Humidity*: A general term referring to the water content of a gas. See *relative humidity*.

*Hydrocarbon cracking*: See *cracking*.

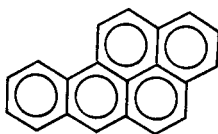
*Hydrocarbons*: Compounds which are composed only of carbon and hydrogen atoms. There are several types of hydrocarbons which are in common use as fuels or in the preparation of polymers, etc.; these differ in the type of bonding present in the molecules. *a) The Alkanes* (sometimes referred to as paraffinic or saturated hydrocarbons) have the general formula, C<sub>n</sub>H<sub>2n+2</sub>. Typical members of this family of compounds are: methane (CH<sub>4</sub>), ethane (C<sub>2</sub>H<sub>6</sub>), propane (C<sub>3</sub>H<sub>8</sub>), butane (CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>), isobutane (CH<sub>3</sub>CH(CH<sub>3</sub>)<sub>2</sub>), etc. *b) The Alkenes* (not recommended are the alternative names, olefinic or unsaturated hydrocarbons, used in some of the older literature): these species are characterized by the presence of a carbon-carbon double bond and have the general formula, C<sub>n</sub>H<sub>2n</sub>; typical members of this family of compounds are: ethene (or

\*Sometimes, the class name "alkene" is used to include also alkadienes, alkatrienes, etc. (i.e., in the sense covered by the obsolescent class term "olefins") thus denoting hydrocarbons C<sub>n</sub>H<sub>2n-2x+2</sub> with any number (x) of carbon-carbon double bonds.

ethylene, CH<sub>2</sub>=CH<sub>2</sub>), propene (or propylene, CH<sub>3</sub>CH=CH<sub>2</sub>), 1-butene (CH<sub>2</sub>=CHCH<sub>2</sub>CH<sub>3</sub>), 2-butene (CH<sub>3</sub>CH=CHCH<sub>3</sub>, exists in either of two stereoisomers, the *cis*- or the *trans*-isomer). *c) The Alkynes*: (sometimes referred to as the acetylenic hydrocarbons) are characterized by the presence of a carbon-carbon triple bond (-C≡C-), and they have the general formula, C<sub>n</sub>H<sub>2n-2</sub>. The simplest members of this family of compounds are: ethyne (acetylene, HC≡CH), propyne (methylacetylene, CH<sub>3</sub>C≡CH). *d) Aromatic hydrocarbons* are characterized by the presence of one or more benzene-like rings, i.e., of six-membered carbocyclic rings in which each carbon atom is only tricoordinated and involved in delocalized ring double bonds (bonds of an order between one and two). The simplest members of this family are: benzene (C<sub>6</sub>H<sub>6</sub>), toluene (methylbenzene, CH<sub>3</sub>C<sub>6</sub>H<sub>5</sub>), *ortho*-xylene (1,2-dimethylbenzene), *meta*-xylene (1,3-dimethylbenzene), *para*-xylene (1,4-dimethylbenzene):

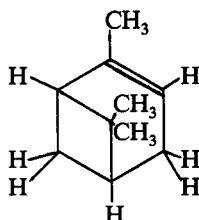


*e) Cycloalkanes* contain a ring of carbon atoms but no multiple bonds. Some common species encountered in this class are: cyclopentane (C<sub>5</sub>H<sub>10</sub>) and cyclohexane (C<sub>6</sub>H<sub>12</sub>). *f) Cycloalkenes* are characterized by the presence of a ring of carbon atoms and double bonded carbon atoms as in the alkenes; an example of this class of hydrocarbon is cyclohexene (C<sub>6</sub>H<sub>10</sub>). *g) Polycyclic aromatics* are aromatic hydrocarbons containing more than one benzene-like ring (cf. section d); an example of this type of species encountered in polluted atmospheres is benzo[*def*]chrysene (formerly called benzo[*a*]pyrene), C<sub>20</sub>H<sub>12</sub>:



Benzo[*def*]chrysene

*h) The natural hydrocarbons:* Although many of the hydrocarbons occur in nature, there are several hydrocarbons which are emitted from trees and plants and which are often referred to as the natural hydrocarbons. Typical members of this class are: isoprene ( $\text{CH}_2 = \text{CH}(\text{CH}_3)\text{CH} = \text{CH}_2$ ) and  $\alpha$ -pinene ( $\text{C}_{10}\text{H}_{16}$ ):



$\alpha$ -Pinene

The reactivity of the various classes of compounds toward the HO-radical and their efficiency in ozone generation in  $\text{NO}_x$ -hydrocarbon-containing air parcels varies greatly; the most reactive hydrocarbons are the alkenes, the aromatic hydrocarbons and natural hydrocarbons having hydrogen atoms at saturated carbon atoms adjacent to a double bond (localized or delocalized); the alkanes and alkynes are least reactive. All hydrocarbons are attacked by HO-radicals in the atmosphere, while only the natural hydrocarbons and the alkenes react at significant rates with ozone.

*Hydrocracking unit:* Used in the thermal decomposition of heavy (high molecular weight) hydrocarbons to smaller (low molecular weight) hydrocarbons; high pressures of hydrogen and a special catalyst are employed. Sulfur compounds in the fuel are reduced to  $\text{H}_2\text{S}$ , and the final hydrocarbon product can be obtained relatively sulfur-free.

*Hydrometeor:* Any condensed water particle in the atmosphere of sufficient size to be potentially capable of undergoing precipitation (in fogs, clouds, some hazes, rain-drops, snow-flakes, etc.).

*Hydrosphere:* The gaseous, liquid, and solid water of the earth (oceans, icecaps, lakes, rivers, etc.) as distinguished from the *lithosphere* and the *atmosphere*.

*Hygrometry and moisture analysis:* The measurement or indication of the water content of the ambient air or of a sample of gas.

*Hygrometer:* Instrument used to measure the water vapour content of the atmosphere. The designs and operations of the various instruments now employed are very different. See the following types:

*Hygrometer, capacitance:* Hygrometer using the capacitance variations of a capacitor whose dielectric medium consists of the gas or of a material in contact with this gas.

*Hygrometer, dew point (cooled surface condensation):* Instrument in which the sample is passed over a cooled surface. The temperature at which dew forms on the cooled surface is a function of the water content of the gas passing over the surface.

*Hygrometer, electrical:* A hygrometer whose sensitive element has electrical properties which vary with the humidity of the gas which traverses the hygrometer.

*Hygrometer, electrolytic:* Hygrometer using a hygroscopic substance (for example, diphosphorus pentoxide,  $\text{P}_2\text{O}_5$ ) which is transformed into an electrolyte (phosphoric acid,  $\text{H}_3\text{PO}_4$ ) in contact with the moisture in the gas. The electrolyte (phosphoric acid) is electrolysed continuously and the electrolysis current is measured. At a constant flow of the gas to be analysed, the electrolysis current is a linear function of the water concentration.

*Hygrometer, frost point:* Instrument in which the sample is passed over a cooled surface. The temperature at which frost forms on it is a function of the water content of the gas passing over the surface.

*Hygrometer, mechanical:* An apparatus containing an element (hair, goldbeater's skin, carbon-film) whose

dimension or mass varies as a function of its water content.

*Hygrometer, psychrometric:* Instrument by which the relative humidity of the atmosphere may be determined. It is generally composed of two temperature sensors, one of which measures the temperature of the air; the other sensor is moistened with water and senses the cooling due to evaporation of water. The temperature difference between the two sensors is a function of relative humidity; sometimes referred to as a "wet- and dry-bulb" hygrometer.

*Hysteresis:* Regarding a material quantity or instrument's reading. Dependence of a value on the direction of change from a previous characteristic value. It may be quantified by the difference between the upscale and downscale variation starting from fixed lower and upper measurement points (inversion).

*Ideal gas:* A gas is considered ideal when its pressure, temperature, and volume follow the relationship:  $pV = nRT$  where  $p$  is the pressure,  $V$  is the volume,  $n$  is the number of moles of gas present,  $R$  is the molar gas constant (SI units,  $\text{J K}^{-1} \text{mol}^{-1}$ ), and  $T$  is the thermodynamic temperature (K). When the pressure is measured in Pa and the volume in  $\text{m}^3$ , then  $R$  equals  $8.3144 \text{ J mol}^{-1} \text{ K}^{-1}$ . With pressure in atm and volume in  $\text{cm}^3$ ,  $R = 82.057 \text{ cm}^3 \text{ atm}^{-1} \text{ mol}^{-1} \text{ K}^{-1}$ . For non-ideal gases, the equation of state is a more complex function of  $p$ ,  $V$ , and  $T$ . For most common gases encountered in atmospheric chemistry, the ideal gas law is followed well at low pressures and up to pressures somewhat above one atm. With compounds such as  $\text{NO}_2$  and formic acid ( $\text{HCO}_2\text{H}$ ) which dimerize easily [forming  $\text{N}_2\text{O}_4$  and  $(\text{HCO}_2\text{H})_2$ , respectively], measured pressures must be corrected using the equilibrium constants for these dimerizations to estimate the amount of the monomer and dimer species present. **GB:** A pure gaseous substance B is treated as an ideal gas when the approximation  $f_B^* = p$  is used (where  $f_B^*$  is the fugacity of B and  $p$  its pressure.)

*Illuminance:* Photometric counterpart of irradiance (not of radiance or intensity). Common units are footcandle, lumens  $\text{cm}^{-2}$ , lumens  $\text{m}^{-2}$ . Not a radiometric quantity, but a photometric quantity. See *luminance*.

*Immission:* A Germanic term, pronounced in English, "eye-mission"; the transfer of pollutants from the atmosphere to a "receptor"; for example, pollutants retained by the lungs. It does not have the same meaning as ground level concentration, but is the opposite in meaning to emission. This term has not been used commonly in the English language.

*Immission dose:* The integral of the immission flow into the receptor over the exposure period.

*Immission flux:* The immission rate divided by the unit surface area of the receptor.

*Immission rate:* The mass (or other physical quantity) of pollutant transferring per unit time into a receptor.

*Impaction:* A forcible contact of particles of matter with a surface.

*Impactor, cascade:* An instrument used for the classification of aerosols according to size and for possible subsequent chemical analysis. Air is drawn through a series of orifices of decreasing size; the air flow is normal to collecting surfaces on which aerosols are collected by inertial impaction. The particles, separated stepwise by their momentum differences into a number of size ranges, are collected simultaneously.

*Impingement:* Equivalent to *impaction*; often refers to impaction on a liquid surface.

*Impinger:* A sampling instrument employing impingement for the collection of particulate matter. Common types are: a) the midget impinger employing impingement in 1-10  $\text{cm}^3$  water, b) the standard impinger employing impingement in 75  $\text{cm}^3$  water, and c) dry impingers. Impingers are also suitable for sampling certain gases and vapours.

*Incinerator:* Equipment in which solid, liquid, or gaseous combustible wastes are ignited and burned. Types include flue-fed and multiple-chamber incinerators with several stages of combustion.

*Individual perception threshold (IPT):* A term used in odor testing which signifies the lowest concentration of a particular species at which a subject indicates both an initial positive and repeated response.

*Inert gas:* A non-reactive gas under particular conditions. For example nitrogen at ordinary temperatures, and the noble gases (helium, argon, krypton, xenon and radon) are unreactive toward most species.

*Inertial separator:* Any dry type collector which utilizes the relatively greater inertia of particles to effect their removal from a gas stream; e.g., cyclonic and impingement separators, gravity settling chambers, and high-velocity gas reversal chambers.

**Infrared gas analyser:** Instruments with various degrees of sophistication are employed to monitor certain species with characteristic infrared absorption bands. E.g., relatively simple systems are employed to detect carbon monoxide (CO) in air; these are built with matching cells, one containing a reference CO sample with the air to be tested in the other. Filtered infrared light which lies largely within the CO absorption region is passed through both cells. In one use of the instrument, the pressure difference which results from the preferential heating of the cell with the higher CO concentration is measured. The signal can be calibrated to yield the CO concentration. Sophisticated infrared systems involving Fourier transform spectrometers or infrared laser diodes are employed to detect particular molecular species of interest in atmospheric chemistry ( $\text{NO}_2$ ,  $\text{H}_2\text{O}_2$ ,  $\text{CH}_2\text{O}$ , CO,  $\text{HNO}_3$ , etc.) and to study their reactions in the real atmosphere or in simulated atmospheres in the laboratory. Long path lengths for the infrared beam are required to detect the small concentrations of most species.

**Instability (with reference to instrumentation):** Change which takes place in instrument reading over a stated period of unattended operation for a given value of the air quality characteristic. It can be characterized by the variation with time of its mean, specifying the drift, and by the dispersion. *Span instability* is the change which takes place in instrument span over a stated period of unattended operation. *Zero instability* is the change in instrument reading in response to a zero sample over a stated period of unattended operation.

**Instantaneous (spot) sampling:** Obtaining a sample of the atmosphere in a period which is short compared with the duration of the sampling exercise. Such samples are often called "grab" samples, a term not recommended. These are useful for the analysis of hydrocarbons and other complicated mixtures of trace gases which are relatively stable in a stainless steel canister or tank and can be transported back to the laboratory for chromatographic or other analysis which cannot be done satisfactorily in the field. The use of plastic bags (constructed of Mylar, FEP Teflon, Tedlar (PVC) or other films) to collect instantaneous samples and to store them for analysis is not recommended. It is very difficult to eliminate pinholes, the reproducibility of heat seals used in constructing the bags is not easy to achieve, gases can permeate through the bag walls, and impurities can be introduced through off-gassing of the bag walls.

**Instrument reading (with reference to air quality measurements):** Output signal of a measuring system obtained as a response related to the concentration or the value of the air quality characteristic.

**Intensity, radiant, spectral (I):** Radiant power per unit solid angle ( $\text{W sr}^{-1}$ ). With the adjective *spectral*, differentiation with respect to wavelength is also implied ( $\text{W sr}^{-1} \text{nm}^{-1}$ ). Unfortunately, several other conflicting definitions of intensity exist, including the power per unit area, and the power per unit solid angle and projected area. The latter definition is common in atmospheric radiative transfer literature, and is synonymous with *radiance*. In spectroscopic literature and in Beer-Lambert law studies, the term *intensity* is used to describe the radiant power of collimated light entering a detector; this definition is synonymous with *irradiance*. These ambiguous uses of *intensity* are so common as to be unavoidable, but unless the definition given above is intended, it is best to use the word only in a generic sense to signify the "amount of light", and then to use the appropriate radiative quantity for numerical calculations. **GB:** The energy per unit time entering a small sphere in a time interval divided by the area of the great circle of the sphere and the time interval. For monodirectional radiation, this reduces to the energy flux density.

**Interferant (GB: interferent):** In measuring the concentration of a constituent of an air sample; any other component that affects the instrument reading. **GB:** A concomitant causing an interference in a sample.

**Inversion height:** The height above ground level at which there is change in sign of the normal temperature "lapse rate",  $dT/dz$  (the rate of change of the temperature with height). Several temperature inversions may be present in the air over a given site at different altitudes as result of various meteorological factors.

**Inversion, temperature:** A departure from the normal decrease of temperature with increasing altitude. A temperature inversion may be produced, for example, by the movement of a warm air mass over a cool one. Intense surface inversions may form over the land during nights with clear skies and low winds due to the radiative loss of heat from the surface of the earth. The temperature increases as a function of height in this case. Poor mixing of the pollutants generally occurs below the inversion, since the normal convective process which drive the warmer and lighter air at ground level to higher altitudes is interrupted as the rising air parcels encounter the warmer air above. Temperature inversions near the surface are particularly effective in trapping ground level emissions.

**Ion: (GB)** An atomic or molecular *particle* having a net electric charge.

**Ionization potential in mass spectrometry:** The minimum electron energy necessary for the production of the molecule ion. The term *ionization energy* is preferred.

*Irradiance, spectral, E*: The incident radiant power per unit projected area of a specified receiving surface ( $\text{W cm}^{-2}$ ). With the adjective *spectral*, differentiation with respect to wavelength is also implied ( $\text{W cm}^{-2} \text{nm}^{-1}$ ). It may be calculated from the radiance ( $L(\lambda, \theta, \phi)$ ) by the cosine-weighted integral over all directions using the relation:

$$E(\lambda) = \int_{\phi} \int_{\theta} L(\lambda, \theta, \phi) \cos\theta \sin\theta \, d\theta \, d\phi$$

This is the radiometric quantity measured with a flat-plate radiometer.

*Isobar*: Lines on a plot joining points of equal barometric pressure in the atmosphere.

*Isokinetic line*: A line in a given surface connecting points with equal wind speed; also called *isotach* or *isovel*.

*Isokinetic sampling*: A technique for collecting airborne particulate in which the sampling device has a collection efficiency of unity for all sizes of particles in sampled air, regardless of wind velocity and direction of the instrument. The air stream entering the collector has a velocity (speed and direction) equal to that of the air in the gas stream just ahead of the sampling port of the collector.

*Isotherm*: Lines joining points of equal temperature in the atmosphere.

*Isotope pattern in mass spectrometry*: Set of peaks related to ions with the same chemical formula but containing different isotopes; e.g., the 16 and 17 mass/charge peaks in a  $\text{CH}_4$  sample arising from  $^{12}\text{CH}_4^+$  and  $^{13}\text{CH}_4^+$  ions.

*Isotropic*: A quantity which is independent of direction. *Anisotropic* and *nonisotropic* refer to quantities which are direction dependent.

*j-values*: An effective first order rate constant for a photochemical reaction (photodecomposition, etc.) of light-absorbing impurities in the atmosphere. It is given by the following relation for the hypothetical photodecomposition of a molecule  $X$  into products  $A + B$  in reaction (I) or by an alternative reactive channel (II) forming  $C + D$ :



$$j_{\text{I}} = \int \sigma(\lambda) \phi_{\text{I}}(\lambda) S(\lambda) \, d\lambda$$

$$j_{\text{II}} = \int \sigma(\lambda) \phi_{\text{II}}(\lambda) S(\lambda) \, d\lambda$$

where  $\sigma(\lambda)$ , is the absorption cross section of the  $X$  species at wave length  $\lambda$ ,  $\phi_{\text{I}}(\lambda)$  and  $\phi_{\text{II}}(\lambda)$  are the primary quantum yields of the reactions (I) and (II), respectively,  $S(\lambda)$  is the actinic flux (or spheradiance). Each quantity is that which applies for the small wavelength interval from  $\lambda$  to  $\lambda + d\lambda$ , and the integral is over all wavelengths for which the  $\sigma\phi S$  product is non-zero. The rates of generation of  $A$  and  $D$  at the particular point in the atmosphere for which  $j_{\text{I}}$  and  $j_{\text{II}}$  apply are given by:  $d[A]/dt = j_{\text{I}}[X]$ ;  $d[D]/dt = j_{\text{II}}[X]$ . In practice the resolution of the available data is often not great enough to allow the integration, and a summation of average quantities over some small wavelength interval is then employed:

$$j_{\text{I}} = \Sigma \bar{\sigma}(\Delta\lambda) \bar{\phi}(\Delta\lambda) \bar{S}(\Delta\lambda), \text{ (similar function for } j_{\text{II}})$$

where the summation is over all wavelength intervals for which the product of terms is non-zero.  $j$ -values are usually given in units of  $\text{s}^{-1}$  or  $\text{min}^{-1}$ . The small  $j$  is preferred to the capital  $J$  in representing  $j$ -values since  $j$  is equivalent to the first order rate coefficient for which a small  $k$  is used (not a large  $K$  which is reserved for equilibrium constants).

*Ketones*: A class of organic compounds of general formula,  $\text{R}(\text{C}=\text{O})\text{R}'$ , where  $\text{R}$  and  $\text{R}'$  are organic groups such as  $\text{CH}_3$ ,  $\text{C}_2\text{H}_5$ , etc. Ketones are products of hydrocarbon oxidation. The simplest ketones are: acetone (propanone,  $\text{CH}_3\text{COCH}_3$ ), 2-butanone (or methyl ethyl ketone,  $\text{CH}_3\text{COC}_2\text{H}_5$ ), 3-pentanone (or diethyl ketone,  $\text{C}_2\text{H}_5\text{COC}_2\text{H}_5$ ). Ketones absorb sunlight ( $\lambda < 320 \text{ nm}$ ) to form radicals by photodecomposition and react with HO-radicals in the atmosphere.

*Kinetics, chemical reaction*: The study of the rates at which reactions occur, the influence of conditions (such as temperature, concentration of reactants, surface/volume ratio, etc.) on these rates, and the determination



of rate coefficients.

**Lachrymator:** A substance which produces a flow of tears in a person or animal (e.g., acetyl chloride, acrylaldehyde, etc.).

**Lapse rate:** The variation of an atmospheric variable with height; unless otherwise stated the variable is temperature.

**Lapse rate, temperature:** The rate of change of temperature with altitude ( $dT/dz$ ). The rate of temperature decrease with increase in altitude which is expected to occur in an unperturbed dry air mass is  $9.8 \times 10^{-3} \text{ }^\circ\text{C m}^{-1}$ . This is called the *dry adiabatic lapse rate*. The lapse rate is taken as positive when temperature decreases with increasing height. For air saturated with  $\text{H}_2\text{O}$ , the lapse rate is less because of the release of the latent heat of water as it condenses. The average tropospheric lapse rate is about  $6.5 \times 10^{-3} \text{ }^\circ\text{C m}^{-1}$ . The lapse rate has a negative value within an inversion layer.

**LIDAR:** An acronym for **L**ight **D**etection **A**nd **R**anging. It is a real time remote sensing technique for the determination of aerosol and trace gas concentrations in air by measurement of scattered laser radiation.

**Lifetime:** The period of time ( $\tau$ ) required for the decay of a given species of initial concentration  $[A]_0$  to  $[A]_0/e$  ( $e = 2.7183$ ). Often applied to species which decay by first order processes in which case  $\tau = 1/k$ , where  $k$  is the first order rate coefficient for the reaction,  $A \rightarrow \text{Products}$ . It is also applied to species which undergo decay by processes which may be second order as well. E.g., if species A is removed by HO-radical reaction and photodecomposition in the atmosphere,  $\text{HO} + A \rightarrow \text{Products}$  (1);  $A + h\nu \rightarrow \text{Products}$  (2), then the lifetime of A is given by:  $\tau = 1/(k_1[\text{HO}] + j_2)$ , where  $k_1$  is the second order rate coefficient for reaction (1),  $[\text{HO}]$  is the HO radical concentration, and  $j_2$  is the first order rate coefficient ( $j$ -value) for reaction (2) for a particular time and place. Sometimes lifetimes are calculated as average lifetimes (global averages over the year, averages for a given latitude, season, etc.) in the atmosphere; in this case average values of  $k_1[\text{HO}]$ ,  $j_2$ , and other loss terms are used. The half-life ( $t_{1/2}$ ) of species A is related to the lifetime by the time required for decay of the species from a concentration of  $C_A$  to  $C_A/2$  and is related to  $\tau$  by  $t_{1/2} = (\ln 2)\tau$ .

**Light scattering:** The redirection of a light beam due to interactions with molecules (Rayleigh and Raman scattering) and aerosols (Mie scattering). Scattered light received at any point in the atmosphere (sometimes called *sky radiation*) is a very important component of the total radiation received from the sun; it is dependent on the solar zenith angle, elevation, aerosol concentration, etc. **GB:** The deflection of a light beam by discrete variation in refractive index due to the presence of particles or by spatial refractive index fluctuations. For *elastic scattering* there is no wavelength shift. For *inelastic scattering* there are wavelength shifts due to molecular transitions (Raman effect, *fluorescence*) and for *quasielastic scattering* there are wavelength shifts and line broadening due to time dependent processes. In *single scattering* there is only one scattering encounter whereas in *multiple scattering* there is successive rescattering of the radiation within the scattering medium.

**Limiting condition of operation:** Range of physical and operational parameters in which the method meets given values of performance characteristics with 95% probability.

**Linear range:** Concentration range over which the intensity of the signal obtained is directly proportional to the concentration of the species producing the signal.

**Lithometeor:** A particle of dry substance in the atmosphere, as contrasted to a hydrometeor.

**Lithosphere:** The crust of the earth, usually thought of as discrete from and in contact with the hydrosphere and the atmosphere.

**Log-normal distribution:** A distribution function  $F(y)$ , in which the logarithm of a quantity is normally distributed, i.e.,  $F(y) = f_{\text{gauss}}(\ln y)$  where  $f_{\text{gauss}}(x)$  is a Gaussian distribution. The size distribution of atmospheric aerosols are often described using this distribution function, although the term also applies to gaseous pollutants.

**Luminance:** Photometric counterpart of radiance, producing the visual sensation called brightness. Typical units are: candela  $\text{m}^{-2}$  (nit), candela  $\text{cm}^{-2}$  (stilb), foot lambert (2.426 nit). As with all photometric quantities, luminance does not refer to a specific wavelength, but applies to light emitted by a standard source (formerly a "standard international candle", now a blackbody radiator emitting at the temperature of solidifying platinum, 2042 K). Conversion from photometric units to radiometric units (e.g.,  $\text{J s}^{-1}$ ) requires convolution over wavelength of the relative spectral response of the human eye (photopic response tables).

**Luminescence:** The emission of light by a molecule or ion which is at temperatures below those required for incandescence. Luminescence can originate from electronically excited states of molecules or ions. If the excited state is short lived, as is the case for excited singlet to ground state singlet electronic transitions, the emission follows excitation within a short time period (about  $10^{-9}$  to  $10^{-6}$  s commonly) and is called *fluorescence*. The fluorescence from the polycyclic aromatic compounds provides a useful means of identification and quantification of these species. If the emitting state undergoes a spectroscopically forbidden transition, for example, an excited triplet to ground state singlet electronic transition, then the emission may be delayed (greater than about  $10^{-3}$  s) following excitation; this emission is called *phosphorescence*. Some molecules (e.g., butanedione) give strong phosphorescence which is useful in identification. *Chemiluminescence* is the emission which results from an excited state formed in a chemical reaction which does not involve light absorption; for example, luminol oxidation by  $H_2O_2$  generates chemiluminescence which can be used for analytical purposes.

**Macrometeorology:** Study of the largest-scale aspects of the atmosphere, e.g., general global circulation.

**Manometer, U-tube:** An instrument for measuring pressure differences. Usually a liquid such as mercury, water, or some low vapour pressure liquid of the desired density is placed in a U-tube. One end of the tube is evacuated and the other is open to the system in which the pressure is to be measured. Differences between the lengths of the liquid columns in the arms (coupled with a knowledge of the density of the liquid) are used to monitor the pressure changes. See also *pressure gauges*.

**Mass balance:** Summation of the masses of a given element in its various compounds before and after reaction (changes) in the atmosphere; provides a test of the completeness of the accounting of the various reaction paths for this element which can be had through the compounds which have been analysed.

**Mass spectrometer:** An instrument used in gas analysis which operates by ionising gaseous atoms or molecules, generally, with electrons of relatively low energy. The parent ions and ion fragments produced are accelerated electrically into a mass separator (involving electric and magnetic fields) which separates ions of specific mass to charge ratio. In a *quadrupole mass spectrometer* the mass separator involves four parallel rods between which a fixed direct current voltage is applied together with a superimposed radiofrequency voltage. *Chemical ionization mass spectrometry* involves the creation of reagent ions by transfer of electrons or protons from an initial ion to a reagent molecule. In *time-of-flight mass spectrometry*, ions produced in an ionizing pulse are accelerated by a given voltage toward a receiver electrode, and the ions of the different mass-to-charge ratios are resolved by their different arrival times at the detector.

**Mass spectrometer, ion source:** generally an assembly composed of: a) an ionization chamber in which a stream of electrons flows from a hot filament across a stream of gas to collector. The potential between filament and collector is usually between 50 and 70 v; b) a device for the acceleration of these ions.

**Mass spectrometer, focusing system; deflection system:** Assembly permitting the separation of ions according to their mass to charge ratio.

**Mass spectrometer, ion collector:** Device for the capture of selected ions such as a Faraday cup collector (with a d.c. amplifier) or an electron multiplier.

**Mass spectrometry, mass peak in:** Record of the ion current, at a specific mass to charge ratio, received by the collector.

**Mass spectrometry, mass range in:** Range of mass numbers which can be characterized by a mass spectrometer with sufficient resolution to differentiate adjacent peaks.

**Mass spectrometry, mass spectrum in:** The series of signals at mass numbers corresponding to the ions produced by the sample; each compound has a characteristic mass spectrum. This is sometimes referred to as the *cracking pattern*.

**Matrix isolation:** In physical chemistry and spectroscopy a term which refers to the isolation of a reactive or unstable species by dilution in an inert matrix (argon, nitrogen, etc.), usually condensed on a window or in an optical cell at a low temperature, to preserve its form for identification by spectroscopic or other means.

**Maximum allowable concentration:** The maximum concentration of a pollutant which is considered harmless to healthy adults during their working hours, assuming they breathe uncontaminated air at all other times.

**Maximum emission concentration:** Standards for maximum concentration of air pollutant emission from stationary or mobile sources.

**Maximum storage life:** Period during which there is no change in concentration in excess of the value of the uncertainty of the concentration.

**Mean:** Two types of means are in common use in atmospheric chemistry: a) *the arithmetic mean* of  $x_i$  given by the following expression:

$$\bar{x} = \frac{\sum_{i=1}^n (x_i)}{n}$$

and b) *the geometric mean* of  $x_i$ , given by:

$$x_g = (x_1 \cdot x_2 \cdot x_3 \dots x_n)^{1/n}$$

**Mean free path ( $\lambda$ ):** The average distance a molecule travels between collisions. For a molecule,  $\lambda = 1/\{(2)^{1/2} \pi n d_m^2\}$  where  $n$  is the number of molecules per unit volume, and  $d_m$  is their mean diameter. For  $O_2$  at one atmosphere and 25 °C, this distance is only  $9.7 \times 10^{-6}$  cm; at  $10^{-6}$  atmospheres and 25 °C it is 9.7 cm. For an aerosol particle, the mean free path,  $\lambda_B$  in the Stokes region (see Stokes law) is given by:  $\lambda_B = (3kT/m)^{1/2} mB$  where  $m$  is the mass of the particle,  $k$  is the Boltzmann constant ( $1.381 \times 10^{-23}$  J K<sup>-1</sup>),  $T$  is the temperature (K), and  $B$  is the mobility.

**Measured value (of air quality characteristic):** Estimated value of the air quality characteristic derived from instrument readings; this usually involves calculations related to the calibration process and conversion to required quantities.

**Measurement resolution (in atmospheric trace component analysis):** The minimum value above which the difference of two values of air quality characteristic can be distinguished with 95% probability.

**Measurement, upper limit of (in atmospheric trace component analysis):** Highest value of the air quality characteristic which can be measured by an instrument; its variations, caused for example by instability, are expected to lie within specified limits. The difference between the lower detection limit and the upper limit of measurement constitutes the *dynamic* range of the instrument.

**Memory effect (in instruments used for atmospheric trace component analysis):** Dependence of an instrument reading on one or several previous sample(s).

**Mesopause:** That region of the atmosphere between the mesosphere and the thermosphere at which the temperature is a minimum.

**Mesoscale:** In meteorology, the size or scale of phenomena smaller than ordinary cyclones or weather systems but larger than such microscale phenomena as the thickness of the boundary layer, the wakes of objects, etc. Thunderstorms involve mesoscale processes, and other meteorological events the size of cities are usually mesoscale processes.

**Mesosphere:** That region of the atmosphere which lies above the stratopause (about 47-52 km) and below the mesopause (about 80-90 km) and in which temperature decreases with increasing height; this is region in which the lowest temperatures of the atmosphere occur.

**Meteorological range:** The distance  $L_v = 3.9/b_{\text{scat}}$ ; this is the distance over which an average observer could just see a large black object against the horizon sky during daytime, under isotropic conditions of  $b_{\text{scat}}$  and illumination.

**Method (as employed in atmospheric trace component analysis):** Procedure for sampling and analysing one or more air quality characteristics. The accuracy may be established using either a reference material or reference procedures. Two or more methods are considered *equivalent methods* if the values for their statistical and functional performance characteristics (for example bias, precision, sensitivity, etc.) and tolerances in the presence of specified interferant(s) and under specified operating conditions, fall within minimum specified limits.

**Microclimatology:** The science that deals with the climate of restricted areas and investigates their phenomena and causes.

*Micrometeorology*: The study of the meteorological processes on scales from a millimeter or less up to tens or hundreds of meters; e.g., meteorology of a local site that is usually small and often is confined to a shallow layer of air next to the ground.

*Middle atmosphere*: The combined stratosphere and mesosphere in the atmosphere.

*Mie scattering*: The scattering of electromagnetic radiation by spherical particles of any size  $r$ , relative to the wavelength,  $\lambda$ . Since the cases  $r \ll \lambda$  and  $r \gg \lambda$  are covered by Rayleigh (dipole) scattering and geometric scattering theories, respectively, Mie scattering often refers to the case of  $r \approx \lambda$ .

*Minimum detection limit*: see *detection limit*, *lower* and *detection threshold*.

*Minimum pressure of utilization*: Lower limiting value of the pressure which still permits the use of the calibration gas mixture. The concentration of the components are no longer guaranteed below this limit for one of the following reasons: desorption of the component of interest occurs as the cylinder pressure drops; desorption of other species such as water vapour occurs as the cylinder pressure drops.

*Mist*: A qualitative term applied to a suspension of droplets in a gas. In the atmosphere a mist produces a generally thin, grayish veil over the landscape. It reduces visibility to a lesser extent than fog but somewhat more than haze (visibility of less than 2 km but greater than 1 km).

*Mixing height*: The height to which significant mixing of added pollutants occurs within the atmosphere. In reference to stack gases, it is considered the height at which stack effluent begins mixing with the atmosphere as it leaves the stack.

*Mixing ratio*: In meteorology, the dimensionless ratio of the mass of a substance (such as water vapour) in an air parcel to the mass of the remaining substances in the air parcel. For trace substances, this is approximated by the ratio of the mass of the substance to the mass of air. However, in the case of water vapour the mass of dry air is used. In atmospheric chemistry, mixing ratios (molecular, molar, by volume, as well as by weight) are used to describe relative concentrations of atmospheric trace gases and impurities; see *concentration*.

*Mobile phase in chromatography*: The carrier fluid with the chemical to be analysed passing through the chromatographic column.

*Mobility*: In aerosol physics, the velocity of a particle per unit applied force.

*Mode*: In a plot of the frequency of occurrence of a variable versus the variable, a maximum point is a mode. A *bimodal* distribution is one which contains two maxima.

*Mole (abbreviated mol)*: The S.I. unit of amount of substance. 1 mol of a substance contains  $6.022 \times 10^{23}$  specified entities. **GB**: The amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

*Monitoring (in atmospheric trace component analysis)*: In a broad sense of the term, repeated measurements to follow changes over a period of time. In a restricted sense of the term, regular measurement of pollutant levels in relation to some standard or in order to assess the effectiveness of a system of regulation and control.

*Monitoring systems (in atmospheric trace component analysis)*: Automatic systems placed in a smokestack, a work place, or in the ambient atmosphere which measure and record the amounts of specified air pollutants which are present.

*Monthly averages (with reference to atmospheric component analysis)*: For reporting integrated analyses of ambient air on a monthly rate, an average value is calculated; i.e., it is given on the basis of a 30-day month.

*Nephelometry*: Analytical methods which depend on the measurement of the intensity of scattered light emanating from an illuminated volume of an aerosol. The ratio of scattered intensity to illuminating intensity is compared with a standard of known properties.

*Network, air sampling*: A number of air sampling stations which are established in a given geographical region at which periodic measurements of both pollutant concentrations and meteorological quantities (wind speed, direction, rain fall, humidity, etc.) are made to determine the extent and the nature of the air pollution and to establish trends in the concentrations of the air pollutants with time.

**Nitric acid ( $\text{HNO}_3$ ):** A major acid formed in the atmosphere from the reaction of HO-radicals with  $\text{NO}_2$  ( $\text{HO} + \text{NO}_2 + \text{M}(\text{N}_2/\text{O}_2) \rightarrow \text{HNO}_3 + \text{M}$ ), also through the reaction of  $\text{N}_2\text{O}_5$  with water droplets ( $\text{N}_2\text{O}_5 + \text{H}_2\text{O}(\text{liquid}) \rightarrow 2\text{HNO}_3$ ), and by reaction of  $\text{NO}_3$  with  $\text{CH}_2\text{O}$  or certain other organic species ( $\text{NO}_3 + \text{CH}_2\text{O} \rightarrow \text{HNO}_3 + \text{HCO}$ ). This is a strong acid and one of the two major acidic components of acid deposition;  $\text{H}_2\text{SO}_4$  is the other.

**Nitric oxide (NO):** The major oxide of nitrogen emitted from combustion sources such as power plants, the exhaust of mobile sources, incinerators, etc. It is an important source of  $\text{NO}_2$  through its oxidation by hydroperoxyl ( $\text{HO}_2$ ) and alkylperoxyl, acylperoxyl, and arylperoxyl radicals ( $\text{RO}_2$ ) and ozone in the atmosphere.

**Nitrogen dioxide ( $\text{NO}_2$ ):** A common impurity in polluted atmospheres which arises from the oxidation of NO released from combustion sources. Its photodecomposition in sunlight of wavelengths less than 420 nm is an important step in the formation of ozone in the polluted troposphere:  $\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}$ ;  $\text{O} + \text{O}_2 + \text{M}(\text{N}_2/\text{O}_2) \rightarrow \text{O}_3 + \text{M}$ . It is also a major source of nitric acid in the troposphere through its reaction with the hydroxyl radical (HO):  $\text{HO} + \text{NO}_2 + \text{M}(\text{N}_2/\text{O}_2) \rightarrow \text{HNO}_3 + \text{M}$ .

**Nitrogen pentoxide (dinitrogen pentoxide,  $\text{N}_2\text{O}_5$ ):** An oxide of nitrogen which forms in the atmosphere through the oxidation of  $\text{NO}_2$  by  $\text{O}_3$ :  $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2$ ;  $\text{NO}_3 + \text{NO}_2 \rightarrow \text{N}_2\text{O}_5$ . Its formation is favored in polluted air masses of high  $\text{O}_3$  and  $\text{NO}_2$  content and during the night. It is a precursor to nitric acid through its reaction with water (liquid) or aqueous aerosols.

**Nitrogen trioxide ( $\text{NO}_3$ ):** A transient species formed in the atmosphere by reaction of  $\text{NO}_2$  with  $\text{O}_3$  ( $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2$ ). It is normally in equilibrium (or more likely approaching equilibrium) with  $\text{N}_2\text{O}_5$  through the reactions,  $\text{NO}_3 + \text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_5$ .  $\text{NO}_3$  absorbs sunlight strongly and is photodissociated rapidly during the day. Its concentration rises at sundown, and it is most readily detected in the atmosphere at night through its strong absorption bands in the 620-660 nm region.

**Nitrous acid (HONO):** A weak acid formed in the troposphere. During the day HONO is formed by the reaction,  $\text{HO} + \text{NO} \rightarrow \text{HONO}$ , but it is rapidly photodecomposed in sunlight ( $\text{HONO} + h\nu \rightarrow \text{HO} + \text{NO}$ ) so that only a very small concentration of HONO is present at that time. In urban communities, a buildup of HONO occurs during the night from unknown sources. Possible sources include homogeneous and heterogeneous reactions such as:  $\text{HO}_2 + \text{NO}_2 \rightarrow \text{HONO} + \text{O}_2$ ; or  $2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HONO} + \text{HNO}_3$ .

**Nitrous oxide ( $\text{N}_2\text{O}$ ):** This oxide of nitrogen is released into the atmosphere through biological activity and from other sources. It does not absorb light which is present within the troposphere, and it is unreactive toward transient species including the HO-radical. Its major loss mechanism involves transport to the stratosphere where it undergoes photodecomposition and reaction with  $\text{O}(^1\text{D})$  to form NO in part. It is present in air at about 0.3 ppmv.

**Normal conditions:** A qualitative term, dependent on the preference of the investigator; it often implies ambient pressure and "room temperature". Preferably the variables of temperature and pressure should be quoted as values representative of the actual conditions (or range of conditions) employed in the study.

**Normal distribution:** See Gaussian distribution function.

**[ $\text{NO}_x$ ]:** The sum of the concentrations or (mixing ratios) of NO and  $\text{NO}_2$ .

**[ $\text{NO}_y$ ]:** The sum of the concentrations or (mixing ratios) of the "reactive" nitrogen compounds in the atmosphere:  $[\text{NO}_y] = [\text{NO}] + [\text{NO}_2] + [\text{NO}_3] + 2[\text{N}_2\text{O}_5] + [\text{HNO}_3] + [\text{HNO}_2] + [\text{CH}_3\text{COO}_2\text{NO}_2] + [\text{HO}_2\text{NO}_2] + [\text{other organic nitrates}]$ .

**Nuisance threshold:** That concentration of an air pollutant that is considered objectionable. In the case of a substance with an objectionable odor, it is the smallest concentration of the substance which can be detected by a human being (nose).

**O-Atoms:** Oxygen atoms occur in the atmosphere in two different electronic states: a)  $\text{O}(^3\text{P})$ , ground state oxygen atoms which are formed largely from  $\text{NO}_2$  photodecomposition for  $\lambda < 420$  nm,  $\text{O}_3$  photodecomposition at  $\lambda > 310$  nm, and quenching of  $\text{O}(^1\text{D})$  atoms by collision with  $\text{O}_2$  and  $\text{N}_2$ . Its major fate in the atmosphere is its reaction with  $\text{O}_2$  to form  $\text{O}_3$ :  $\text{O} + \text{O}_2 + \text{M}(\text{N}_2/\text{O}_2) \rightarrow \text{O}_3 + \text{M}$ . b)  $\text{O}(^1\text{D})$ , oxygen atoms in the first electronically excited state, are formed in  $\text{O}_3$  photolysis at  $\lambda < 310$  nm. This species is the major source of HO-radicals in the atmosphere through its reaction with  $\text{H}_2\text{O}$ :  $\text{O}(^1\text{D}) + \text{H}_2\text{O} \rightarrow 2\text{HO}$ . In the upper atmosphere highly excited  $\text{O}(^1\text{S})$  atoms also are generated.

*Odor threshold:* The concentration of a compound which produces an odor which is detectable by a human being (nose). For certain compounds this threshold is very low (e.g., 1 part in  $10^9$  for certain sulfides).

*OH-Radical:* See HO-radical.

*Open burning:* The occasional burning of outdoor stores of lumber, sawdust, scrapped cars, tires, textiles, open dumps, etc.

*Open hearth furnace:* Reverberatory furnace, containing a basin-shaped hearth, for melting and refining suitable types of pig iron, iron ore, and scrap for steel production. A large amount of dust from ore and other materials and splashings from slag are carried away by the waste gases; a supplementary chamber is commonly used for collecting slag and dust.

*Organylperoxyl radical ( $RO_2$ ):* A radical formed in the reaction sequence which follows HO-radical attack on hydrocarbons (RH) and their oxidation products:  $HO + RH \rightarrow H_2O + R$ ;  $R + O_2 \rightarrow RO_2$ ; typical alkylperoxyl radicals are:  $CH_3O_2$ ,  $C_2H_5O_2$ ,  $n-C_3H_7O_2$ , etc. In an  $NO_x$ -containing air mass, these radicals react to oxidize NO to  $NO_2$  ( $RO_2 + NO \rightarrow RO + NO_2$ ) as part of the chain reaction which leads to ozone generation in the troposphere.

*Overfire:* High-velocity air jets issuing from nozzles in a furnace enclosure to provide turbulence and oxygen to aid combustion, or to provide cooling air; *overfire* air is also known as *secondary* air.

*Oxidant (with reference to atmospheric chemistry):* A very qualitative term which includes any and all trace gases which have a greater oxidation potential than oxygen (for example, ozone, peroxyacetyl nitrate, hydrogen peroxide, organic peroxides,  $NO_3$ , etc.). It is recommended that alternative, more definitive terms be used which define the specific oxidant of interest whenever possible.

*Oxidation:* The chemical process by which the oxidation state of an atom in a element, ion, or compound is increased.

*Oxidation state (oxidation number):* A measure of the degree of oxidation of an atom in a substance. It is defined as the charge an atom might be imagined to have when electrons are counted according to an agreed-upon set of rules: 1) The oxidation state of a free element (uncombined element) is zero; 2) for a simple (monatomic) ion, the oxidation state is equal to the net charge on the ion; 3) Hydrogen has an oxidation state of 1 and oxygen has an oxidation state of -2 when they are present in most compounds. (Exceptions to this are that hydrogen has an oxidation state of -1 in hydrides of active metals, e.g., LiH, and oxygen has an oxidation state of -1 in peroxides, e.g.,  $H_2O_2$ ); 4) the algebraic sum of oxidation states of all atoms in a neutral molecule must be zero, while in ions the algebraic sum of the oxidation states of the constituent atoms must be equal to the charge on the ion. For example, the oxidation states of sulfur in  $H_2S$ ,  $S_8$  (elementary sulfur),  $SO_2$ ,  $SO_3$ , and  $H_2SO_4$  are, respectively: -2, 0, +4, +6, and +6. The higher the oxidation state of a given atom, the greater is its degree of oxidation; the lower the oxidation state, the greater is its degree of reduction. See also **GB**.

*Oxidized species:* In chemistry, a term used to characterize the degree of oxidation (or reduction) in atoms, molecules, and ions. An atom in a molecule or an ion which has a high oxidation state. An element or atom in a compound can be oxidized by reaction with oxygen, while it can be reduced by reaction with hydrogen. An oxidized species may be formed also through the loss of electrons (either to the positive electrode in a cell, or through transfer to another atom or group of atoms). For example, the sulfur in  $H_2S$  is reduced sulfur relative to elementary sulfur, while in  $SO_2$  and  $SO_3$  are oxidized. Metallic iron (Fe) is a reduced state of iron, while the  $Fe^{+2}$  ion (ferrous ion) and  $Fe^{+3}$  ion (ferric ion) are oxidized states of iron.  $Fe^{+3}$  is in a higher oxidation state than  $Fe^{+2}$  which is in a higher oxidation state than Fe. See *oxidation state*.

*Oxygen, molecular ( $O_2$ ):* A reactive species which comprises about 21% by volume of the gases present in the earth's atmosphere. It is a necessary species for the existence of most forms of life on earth. It is a highly reactive gas which is capable of combining with most of the other elements. See also *ozone*, *O-atoms*.

*Ozone ( $O_3$ ):* A highly reactive compound which occurs in the atmosphere. It is formed in the stratosphere through the photolysis of molecular oxygen at wavelengths less than 240 nm: ( $O_2 + h\nu \rightarrow 2O$ ;  $O + O_2 + M(N_2/O_2) \rightarrow O_3 + M$ ). The stratospheric ozone acts as a protective shield which filters the wavelengths of sunlight which enter the lower atmosphere to those longer than about 290 nm. Ozone is a common secondary pollutant which is formed in a polluted air mass through the action of sunlight on  $NO_2$  ( $NO_2 + h\nu \rightarrow O + NO$ ;  $O + O_2 + M(O_2/N_2) \rightarrow O_3 + M$ ). This is the most abundant of the oxidants formed in photochemical smog.

**Ozone hole:** A region of the stratosphere over Antarctica in which a marked decrease in the concentration of ozone has been observed in the Antarctic spring in recent years. The origin of this phenomenon is not yet established, but several theories based on both physical (transport related) and chemical processes (involvement of the halocarbons and their products of oxidation) have been suggested. The latter explanation appears to be in better accord with recent findings.

**PAH:** Polycyclic aromatic hydrocarbons; see *hydrocarbon, aromatic*.

**Particle (atmospheric):** A small discrete mass of solid or liquid matter.

**Particle counter:** A device for measuring the number of suspended particles (in a certain size range) per volume unit of a gaseous or liquid medium.

**Particle size:** To describe the size of liquid or solid particles (aerosol) the average or equivalent diameter is used. For nonspherical particles collected in an impactor, for example, the aerodynamic diameter of a particle of arbitrary shape and density refers to the size of a spherical particle of unit density that would deposit on a given impactor surface.

**Particle size distribution:** The size of the liquid or solid particles in the atmosphere usually extends from  $>0.01$  to  $<100 \mu\text{m}$  in diameter. In the earth's atmosphere the distribution function which describes the number of particles as a function of diameter, mass, or surface area of the aerosol can be determined reasonably well with modern instrumentation.

**Particulate matter:** A general term used to describe airborne solid or liquid particles of all sizes. The term *aerosol* is recommended for general use in describing airborne particulate matter.

**Passive sampler:** A device for preconcentration of trace substances from gaseous media based on molecular diffusion without controlled conveyance of the gas to be investigated (e.g., work place air).

**PCB:** Polychlorinated biphenyls; toxic compounds which have been employed as insulating fluids in some electrical transformers.

**Peak, chromatographic: (GB)** The portion of a differential chromatogram recording the detector response or eluate concentration while a single compound emerges from the column. If separation is incomplete, two or more components may appear as one unresolved peak.

**Peak concentration (trace atmospheric component):** The highest concentration of a given trace component which was measured with a continuous analyser during a specified sampling period.

**Period of unattended operation:** Period for which given values of performance characteristics of an instrument can be guaranteed to remain within 95% probability without servicing or adjustment.

**Permeation tube:** A device used for dynamic preparation of test gas mixtures by means of controlled permeation of a gaseous analyte out of a container through polymer material into a carrier gas stream. These devices containing certain condensable gases (e.g.,  $\text{NO}_2$ ,  $\text{SO}_2$ , etc.) when operated at closely controlled temperatures can be used as primary standards calibrated in terms of the weight loss per unit time.

**Peroxy organic radical:** see *organylperoxy radical*.

**pH:** A measure of the acidity of aqueous solutions. As originally defined by Sørensen in 1909, the quantity  $\text{pH} = -\lg[\text{H}^+]$ . However since activities of hydrogen ion (and not hydrogen ion concentrations) are measured by means of pH meters which employ an electrochemical cell (often a glass electrode), it is logical to define pH in terms of the activity of hydrogen ion ( $a_{\text{H}^+}$ ) in solution:

$$\text{pH} = -\lg(a_{\text{H}^+})$$

The pH of pure water (25 °C) = 7.0; acid solutions have values of  $\text{pH} < 7$  while basic solutions have  $\text{pH} > 7$ . **GB:** The concept of pH is unique amongst physicochemical quantities in that, in terms of its (notational) definition given in the above equation, involving as it does a single ion activity, it is immeasurable. It is therefore defined operationally in terms of the operation or method used to measure it. The electromotive force  $E_x$  of the cell:

Pt,  $\text{H}_2$  | solution X | concentrated KCl solution | reference electrode

is measured and likewise the electromotive force  $E_s$  of the cell:

Pt, H<sub>2</sub> | solution S | concentrated KCl solution | reference electrode

both cells being at the same temperature throughout and the reference electrodes and bridge solutions being identical in the two cells. The pH of the solution X, denoted by pH(X), is then related to the pH of the solution S, denoted by pH(S), by the definition:

$$\text{pH(X)} = \text{pH(S)} + \frac{(E_s - E_x)F}{RT \ln 10}$$

where  $R$  denotes the gas constant,  $T$  the thermodynamic temperature, and  $F$  the Faraday constant ( $9.64853 \times 10^4$  coulomb (C) mol<sup>-1</sup>). Thus defined the quantity pH is a number.

*Phase:* In chemistry, a physically distinct, homogeneous portion of a heterogeneous mixture.

*Photochemical reaction:* A reaction involving an electronically excited state of a molecule or atom which can occur following light absorption of sufficient energy per quantum (usually ultraviolet or visible radiation). In electronically excited molecules one of several types of photochemical reaction may occur: photodecomposition into molecular fragments or radicals, photodecomposition into stable, smaller products, photoisomerization, intersystem crossing (a singlet to triplet state, etc.), internal energy conversion (e.g., excited singlet to vibrationally excited, singlet ground state), fluorescence, phosphorescence, electronic or vibrational energy quenching, etc.

*Photochemical Smog:* The resulting mix of ozone, peroxyacetyl nitrate, aldehydes and other oxidation products of the hydrocarbons, oxides of nitrogen, aerosols, etc., which form in highly polluted urban atmospheres under conditions of stagnation and high sunlight intensity in cities such as Los Angeles, California. Most large cities in the world show some degree of photochemical smog generation today. Photochemical smog is a highly oxidizing atmosphere in contrast with the SO<sub>2</sub>-rich pollution and fogs which characterized many cities such as London, England, many years ago. The characteristics of photochemical smog also include eye-irritation, visibility reduction, damage to certain sensitive plants and trees, and possible pulmonary and other health-related problems in humans and animals.

*Photochemistry:* The chemistry of excited electronic states of atoms and molecules formed by the absorption of light by an atom or molecule. The primary processes in photochemistry of a given compound are the various reaction channels of the electronically excited species. These can be molecular decomposition into stable molecules or radicals, molecular isomerization, fluorescence, phosphorescence, electronic quenching by collision, etc. The reactions of the molecular fragments which are formed photochemically, are correctly referred to as thermal reactions, in that they are analogous to the reactions induced following thermal decomposition at high temperatures. The term photochemistry is sometimes used incorrectly by atmospheric scientists to refer both the photochemical reactions of the electronically excited species as well as the purely thermal reactions of the atoms, free radicals and molecules which are present in the atmosphere.

*Photolysis:* Although it means literally the cleavage of a bond by light, it has been used incorrectly to indicate the act of irradiating a substance with light. Specific terms such as *photodecomposition*, *photoisomerization*, *photodissociation*, which describe the physical consequences of the irradiation are more descriptive and are recommended terms.

*Photometry:* The measurement of light over wavelengths which produce visual sensation (approximately 380-780 nm). Thus photometric quantities do not refer to a specific wavelength but to the light emitted by a standard source (formerly a "standard international candle", now a blackbody radiator emitting at the temperature of solidifying platinum, 2042 K). *Luminance* and *illuminance* are the photometric analogues of the radiometric quantities *radiance* and *irradiance*, respectively, but conversion from photometric units (e.g., lm cm<sup>-2</sup>) to radiometric units (e.g., J s<sup>-1</sup> cm<sup>-2</sup>) requires convolution over wavelength of the spectral radiation with the relative spectral response of the human eye. The standard response is called the "spectral luminous efficiency of radiation", and is tabulated for daylight adapted vision in photopic response tables.

*Photophoresis:* In aerosol physics, the motion of particles due to the influence of light. In many cases, this amounts to a special form of thermophoresis due to the heating of the particles by the light.

*Photostationary state:* Highly reactive species in the atmosphere are often destroyed at a rate which is approximately equal to that at which they are formed. If the process of formation or destruction of such a



species is initiated by light, then the reactive species is said to be in a photo-stationary state. The concentration of such species adjusts to changes in the actinic flux (time of day, cloud-cover, etc.) and other reactant concentrations. The system of ozone, nitric oxide and nitrogen dioxide in the sunlight-irradiated troposphere achieves a photostationary state when NO is the major reactant to destroy ozone; for these conditions the reactions are:  $\text{NO}_2 + h\nu \rightarrow \text{O}(^3\text{P}) + \text{NO}$  (1);  $\text{O}(^3\text{P}) + \text{O}_2 + \text{M}(\text{N}_2/\text{O}_2) \rightarrow \text{O}_3 + \text{M}$  (2);  $\text{O}_3 + \text{NO} \rightarrow \text{NO}_2 + \text{O}_2$  (3). At the photostationary state the concentration of ozone is given by:  $[\text{O}_3] = ([\text{NO}_2]/[\text{NO}])(j_{\text{NO}_2}/k_3)$ , where  $j_{\text{NO}_2}$  is the effective first order rate coefficient for reaction (1) for the given conditions of actinic flux, and  $k_3$  is the second order rate coefficient for reaction (3) at the appropriate temperature of the atmosphere. Deviations from the  $\text{O}_3$ , NO,  $\text{NO}_2$  photo-stationary state are expected in theory and are observed in the atmosphere when reaction (3) does not dominate the  $\text{O}_3$  loss mechanisms, e.g., at low  $[\text{NO}]$ .

*Photosynthesis*: A metabolic process involving plants and some types of bacteria (e.g., Chromataceae, Rhodospirillaceae, Chlorobiaceae) in which light energy absorbed by chlorophyll and other photosynthetic pigments results in the reduction of  $\text{CO}_2$  followed by the formation of organic compounds. In plants the overall process involves the conversion of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  to carbohydrates (and other plant material) and the release of  $\text{O}_2$ .

*Phytotoxicant*: An agent which produces a toxic effect in vegetation.

*Plant damage*: Damage to living plants by certain air pollutants ( $\text{SO}_2$ , certain metal fluorides,  $\text{O}_3$ , peroxyacetyl nitrate, nitrogen oxides, etc.) often is evident as leaf tissue collapse, chlorosis, and growth alteration.

*Plume*: The gaseous and aerosol effluents which are emitted from a chimney and the volume of space which they occupy (often visible). The shape of the plume and the concentrations of pollutants in it at various points along the path of the plume are sensitive functions of the meteorology, local topography, and the chemistry which occurs in the plume. *Urban plumes* are observed over many urban areas and downwind of these areas in which a combination of man sources of pollution are concentrated.

*Polycyclic compounds*: Compounds of a structure containing more than one ring (cyclic series of covalent bonds); see also *polycyclic aromatic hydrocarbons*. Atoms of elements other than carbon and hydrogen may be present in these ring structures (nitrogen, sulfur, oxygen, etc.).

*Potential temperature*: The temperature that a dry air parcel would have if lowered or raised adiabatically to level of 1000 mbar pressure (or other arbitrary standard pressure).

*Potentiometer*: a) In electronics, a potentiometer is a sensitive voltage measuring device based on a null technique which provides infinite impedance at null; b) in chemistry, potentiometric methods involve the measurement with a potentiometer of voltage generated in a cell. A high impedance digital voltmeter is often used today as a convenient alternative to a potentiometer.

*Precipitation, in chemistry*: The sedimentation of a solid material from a liquid solution in which the material is present in amounts greater than its solubility in the liquid.

*Precipitation, electrostatic*: Separation of particles or droplets suspended in a gas or air. A large potential difference (12 to 30 kV dc) is required between the spaced electrodes in the precipitator. The charged particles are attracted to an electrode of opposite charge and collected.

*Precipitation, in meteorology*: Rain, snowfall, hail, etc.

*Precision (reproducibility)*: The closeness of agreement between the results obtained by applying a given experimental procedure several times under prescribed conditions. The smaller the random part of the experimental errors which affect the results, the more precise is the method. A term not to be confused with *accuracy* which is a measure of the agreement between the true value and the measured value.

*Precursor*: A chemical compound which is released into the atmosphere, undergoes chemical change, and leads to a new (secondary) pollutant, is called a precursor of that species.

*Preexponential factor*: The term  $A$  which appears in the Arrhenius form of the rate coefficient expression,  $k = Ae^{-E_a/RT}$ ; see *rate coefficient*.

*Pressure, gauge*: The difference in pressure existing within a system and that of the atmosphere. Zero gauge pressure is equal to the atmospheric pressure.

**Pressure gauges:** Devices for measuring the pressure in a system: *a) Bourdon tube gauge:* A device in which the responsive element is a blind, curved elastic tube, oval in cross section and open at one end to the systems of which the pressure is to be measured. The body of the gauge is at atmospheric or some other controlled pressure. Increasing pressure within the gauge causes the radius of curvature to increase, and this motion drives an indicator. *b) Capacitance gauge:* A device in which a metal coated diaphragm serves as one plate of a capacitor. A reference pressure is applied to one side of the diaphragm and the pressure to be measured is applied to the other. Changes in pressure, change the capacitance which is transformed to a pressure reading by the device. Such devices are highly sensitive and are available commercially for a wide range of pressures. *c) Dead weight piston gauge:* An absolute pressure measuring device, usually used for calibration of other types of pressure measuring devices. It consists of a hydraulic system equipped with a cylinder and a piston of accurately known area. Pressure is applied to the hydraulic system and weights are added externally to the piston until the external force exerted by the piston equals the force exerted by the hydraulic system. The pressure exerted by the hydraulic system can be calculated from the combined weight of the piston and the added weights, and the area of the piston.

**Pressure, static:** The pressure of a fluid at rest, or in motion exerted perpendicularly to the direction of flow.

**Primary mixture:** A mixture obtained directly from two or more components intended for the preparation of more dilute calibration mixtures (called secondary or tertiary mixtures).

**Primary pollutant:** A pollutant emitted directly into the air from identifiable sources (e.g., SO<sub>2</sub>, NO, hydrocarbons, etc.). **Secondary pollutants,** such as ozone, are generated within the atmosphere through chemical changes which occur in primary pollutants.

**Probe (in stack gas sampling):** A device, commonly in the form of a tube, used for sampling or measurement inside a duct, stack, volcano, vent, etc.

**Psychrometry:** The use of a wet-and-dry-bulb thermometer for measurement of atmospheric humidity.

**Quality assurance:** The guarantee that the quality of a product (analytical data set, etc.) is actually what is claimed on the basis of the quality control applied in creating that product. Quality assurance is not synonymous with quality control. Quality assurance is meant to protect against failures of quality control.

**Quality control:** The maintenance and statement of the quality of a product (data set, etc.) specifically that it meets or exceeds some minimum standard based on known, testable criteria.

**Quantum of light:** A photon or "particle" of light; this has an energy given by  $E = hc/\lambda$  where  $h$  is the Planck constant,  $c$  the velocity of light, and  $\lambda$  the wavelength of light.

**Quantum yield:** a) For primary processes this is the fraction of electronically excited molecules which decompose, isomerize, fluoresce, or react by some other specific pathway. If the excited molecule of  $X$  decomposes by reaction (I),  $X + h\nu \rightarrow A + B$  (I), then the quantum yield of this process is symbolized by  $\phi_1$ . If there are  $n$  different primary processes in which the excited state is involved, then the following relation must hold:

$$\sum_{i=1}^n \phi_i = 1.0$$

b) For secondary products formed in the thermal reactions which follow the primary photochemical steps, the quantum yield of any stable product ( $C$ ) is defined as the number of molecules of  $C$  formed in the system during a given short time period divided by the number of light quanta absorbed by  $X$  in the system during this time period. This quantum yield may be any number. It is often symbolized using a capital phi (e.g.,  $\Phi_C$ ) to distinguish it from the primary quantum yield; thus the quantum yield of hydrogen chloride ( $\Phi_{\text{HCl}}$ ) can be as high as  $10^6$  in irradiated mixtures of Cl<sub>2</sub> and H<sub>2</sub> where chain reactions are important; see chain reaction. **GB:** The number of moles transformed in a specified process, physically (e.g., by emission of photons) or chemically, per mole of photons absorbed by the system.

**Radiance:** The radiance,  $L(\lambda, \theta, \phi)$  is defined as  $L(\lambda, \theta, \phi) = dQ/(\cos\theta \, ds \, d\omega \, dt \, d\lambda)$ , where  $dQ$  is the radiant (light) energy in the wavelength interval  $\lambda$  to  $\lambda + d\lambda$  which is transported across a particular surface element of area  $ds$ , in time  $dt$ , originating from a solid angle  $d\omega$  which is at an angle  $\theta$  to the surface normal. Thus, the radiance specifies the energy emanating from an extended source, measured per unit time, unit solid angle, unit wavelength, and unit area of a surface perpendicular to the direction of incidence. In contrast to the actinic flux and the irradiance, the radiance has complete information about the direction of incidence of the light. The adjective "spectral" is often used with "radiance" to emphasize its wavelength dependence. The term

"intensity" is often used instead of "radiance".

**Radical (or free radical):** A reactive atom or a fragment of a stable molecule which contains an odd number of bonding electrons. These reactive species have very short lifetimes in the lower atmosphere and low concentrations, although they are responsible for much of the chemical transformations in the atmosphere. Typical radical species encountered in atmospheric chemistry are: HO, HO<sub>2</sub>, Cl, ClO, NO<sub>3</sub>, CH<sub>3</sub>O<sub>2</sub>, C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, etc. The concentrations show strong diurnal variations. NO and NO<sub>2</sub> are technically radicals as well (since they have an odd-number of bonding electrons), but they do not exhibit the high reactivity normally associated with typical radicals. Some chemists (from Great Britain and elsewhere) follow a practice of coupling with the formula of a radical, a dot placed near the atom in the radical which is judged to have the highest probability for the location of the odd electron. Thus the *n*-propyl and isopropyl radicals may be written as CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub><sup>•</sup> and (CH<sub>3</sub>)<sub>2</sub>CH<sup>•</sup>, respectively. Although this practice is not followed today by many of the atmospheric scientists, its use has some value in that it allows a rapid recognition of a radical species and of its reactive site. **Biradicals** contain two unpaired electrons, e.g., O(<sup>3</sup>P), CH<sub>2</sub>(triplet), CH<sub>2</sub>OO (Criegee intermediate), O<sub>2</sub>(ground state) etc. **Radical ions** are charged radicals (most common in solution phase reactions). **GB:** At least in the context of physical organic chemistry, it seems desirable to cease using the adjective "free" in the general name of this type of *chemical species* and molecular entity, so that the term free radical may in future be restricted to those radicals which do not form parts of *radical pairs*.

**Radiometry:** The measurement of quantities associated with radiant energy. The quantities may also describe the variation of the energy with respect to other variables such as wavelength, time, position, direction (solid angle), area normal to the light, or projected area of emitting or receiving surfaces. For example, see *intensity*, *radiance*, *irradiance*. If the light is monochromatic, it is sometimes convenient to replace the radiant energy by the corresponding number of photons (or quanta) which is obtained by dividing the energy by  $hc/\lambda$  where  $h$  is the Planck constant,  $c$  the velocity of light, and  $\lambda$  the wavelength of the light.

**Radiosonde:** A miniature radio transmitter with instruments in a package that is carried aloft (e.g., by an unmanned balloon) for broadcasting every few seconds by means of precise tone signals or other suitable method, the humidity, temperature, pressure, or other parameter.

**Rain out:** The mechanism by which small particles in the clouds are removed by the formation of rain-drops; this is a different mechanism from *wash out* which is a process which occurs below cloud level. Both the terms *rain out* and *wash out* have not always been used in accordance with these definitions. For clarity they should be replaced by the term, *in-cloud scavenging* and *below-cloud scavenging*, respectively.

**Rate coefficient:** A coefficient (sometimes referred to as a *rate constant*) that appears in a rate equation which relates the rate of a chemical reaction and the concentrations of reactants: first order rate coefficient,  $k_1$  in the relation,  $-d[A]/dt = [A]k_1$ , where  $[A]$  is the concentration of species A. Second order rate coefficient,  $k_2$  in the relation,  $-d[A]/dt = [A][B]k_2$ . Third order rate coefficient,  $k_3$  in the relation,  $-d[A]/dt = [A][B][C]k_3$ ; A, B, and C represent reactant molecules, and A, B, and C may be the same or different molecules. Many reactions which involve the association of two radicals (e.g., HO + NO<sub>2</sub> + M(N<sub>2</sub>/O<sub>2</sub>) → HONO<sub>2</sub> + M) have second order rate coefficients which are pressure dependent and show a transition between third order at low pressures (direct dependence on  $[M]$ ) to second order (independent of  $[M]$ ) at high pressures. *Troe* expressions are often used to describe these. Some complex or composite reactions (e.g., chain reactions, heterogeneous reactions, solution phase reactions, etc.) have rate equations of a more complex form (fractional powers on the concentrations, ratios of concentrations, etc.). The term *rate coefficient* rather than *rate constant* is preferred since the  $k$  values are commonly dependent on temperature, total pressure, etc. Also in a composite reaction the measured rate coefficient may depend on a concentration term. Rate coefficients for photodissociation (called *j-values*) apply to photochemical reactions such as NO<sub>2</sub> +  $h\nu$  → O(<sup>3</sup>P) + NO; see *j-value*.

**Rate constant:** see *rate coefficient*.

**Rayleigh scattering:** The scattering of light by particles and molecules which are much smaller than the wavelength of the light. In the ideal case, the process is one of pure dipole and induced dipole interactions with the electric field of the light wave. The scattering cross section for light of wavelength  $\lambda$  is proportional to  $\lambda^{-4}$ .

**Reaction, elementary:** A chemical reaction which describes a single step in a chemical reacting system. The formation of final products from initial reactants always takes place by one or more relatively simple steps (elementary reactions) in each of which the extent of transfer of atoms and molecular decomposition or rearrangement is very limited (a simple bond cleavage, etc.). **GB:** A reaction in which no reaction intermediates have been detected, or need to be postulated in order to describe the chemical reaction on a molecular scale. Until evidence to the contrary is discovered, an elementary reaction is assumed to occur in

a single step and to pass through a single transition state.

**Reaction mechanism:** A series of elementary reactions which describes the detailed chemical changes which occur in a chemically reacting system. **GB:** A detailed description of the pathway leading from the reactants to the products, including as complete a characterization as possible of the composition, structure and other properties of reaction intermediates and transition states. An acceptable mechanism of a specified reaction (and there may be a number of such alternative mechanisms not excluded by the evidence) must be consistent with the reaction stoichiometry, the rate law, and all other available experimental data, such as the stereochemical course of the reaction. Inferences concerning the electronic and nuclear motions which dynamically interconvert successive species along the reaction path, are often included in the description of a mechanism.

**Recovery:** The percentage yield of added analyte after it has passed a sequence of operations constituting a particular analytical scheme.

**Reduced species:** In chemistry, a term used to characterize the degree of reduction (or oxidation) in atoms, molecules, and ions. An atom in a molecule or an ion which has a low *oxidation state*. An element or atom in a compound can be reduced by the reaction of an element or compound with hydrogen, while it can be oxidized by reaction with oxygen. A reduced species can be formed also through the gain of electrons (either at the negative electrode in a cell or through transfer from another atom, ion, or group of atoms in a chemical reaction). For example, the carbon atom in  $\text{CH}_4$  and other hydrocarbons is in a reduced state, while the carbon in  $\text{CO}_2$  is in an oxidized state. Similarly the sulfur atom in  $\text{H}_2\text{S}$  is in a reduced state while that in sulfuric acid ( $\text{H}_2\text{SO}_4$ ) is in an oxidized state. See *oxidation state*.

**Reduction:** The chemical process by which the oxidation state of an atom in an element, ion, or compound is reduced.

**Reference material:** A substance or mixture of substances, the composition of which is known within specified limits, and one or more of the properties of which is sufficiently well established to be used for the calibration of an apparatus, the assessment of a measuring method, or for assigning values to materials. Reference materials are available from national laboratories in many countries (e.g., National Institute for Standards and Technology (NIST), U.S.A.; Community Bureau of Reference, U.K.).

**Reference procedure (in analysis of trace air constituents):** Agreed method for determining one or more air quality characteristics where it is not practical to produce a reference material; the result obtained is defined as the measure of the air quality characteristic. For example, a gas such as  $\text{NO}_2$  may be somewhat unstable when stored in a tank at low mixing ratios, so that the use of a more stable  $\text{NO}$  standard mixture in  $\text{N}_2$  may be oxidized to  $\text{NO}_2$  by  $\text{O}_3$  in a specified manner referred to as the  $\text{NO}_2$  reference procedure.

**Reflectance, spectral, directional:** For a surface receiving radiation, ratio of the reflected radiant exitance to the incident irradiance. It may depend on wavelength and on direction of incidence, as indicated by the prefixes.

**Relative density:** The ratio of the density of a given substance to the density of a reference material at specified conditions of temperature and pressure; in the older literature this is called *specific gravity*.

**Relative humidity:** The ratio, often expressed as a percentage, of the partial pressure of water in the atmosphere at some observed temperature, to the saturation vapour pressure of pure water at this temperature.

**Remote sensing (in atmospheric sciences):** The determination of substances in the atmosphere, or in emissions, or of meteorological parameters in the atmosphere, by means of instruments not in immediate physical contact with the sample being examined.

**Repeatability:** Qualitatively, the closeness of agreement between successive results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory and short intervals of time). Quantitatively, the value below which the absolute difference between two single test results obtained in the above conditions may be expected to lie with a specified probability. In the absence of other indication, the probability is normally 95%.

**Reproducibility:** Qualitatively, the closeness of agreement between individual results obtained with the same method on identical test material but under different conditions (different operators, different apparatus, different laboratories and/or different times). Quantitatively, the value below which the absolute difference between two single test results on identical material obtained by operators in different laboratories, using the

standardized test method, may be expected to lie with a specified probability. In the absence of other indication, the probability is 95%.

**Residence time:** a) *Instrumentation*: The time required for air or reagent parcel to pass from the entrance to the exit of an instrument. Often this is approximated as the ratio of the interior volume of the device to the flow rate. b) *Atmospheric*: The average time a molecule or aerosol spends in the atmosphere after it is released or generated there. For compounds with well defined sources and emission rates, this is estimated by the ratio of the average global concentration of a substance to its production rate on a global scale. It is a function of not only the emission rates but the loss rates by chemical and physical removal processes.

**Residual fuel/oil**: The liquid or semiliquid, high-boiling fraction of residue from the distillation of petroleum which is used as a fuel. After removal of the lower boiling fraction of crude oil, sold as petroleum gas, the somewhat higher boiling fraction becomes gasoline and diesel oil. A portion of the higher boiling fraction is "cracked" to yield additional gasoline. Still heavier oils become lubricants. Paraffin, asphalt, etc., are also extracted from the crude oil. It is the remaining residual oil, not economically usable for other industrial purposes, which is then sold as a relatively low cost fuel for burning.

**Residual spectrum/background spectrum in mass spectrometry**: Set of peaks recorded in the absence of a sample and due either to small air leaks or to the presence of molecules desorbed from the walls of the introduction device or the source, or from the pump fluid.

**Resolution in mass spectrometry**: A number which expresses the possibility of separation of two ions of mass  $m_a$  and  $m_a + \Delta m_a$  in a mass spectrometer. It is given with the ratio, expressed as a percentage, of the valley height to the height of two adjacent peaks, of equal height, considered in those conditions. For example:  $m_a/\Delta m_a = 100$  at 10% valley.

**Resolution in gas chromatography**: A characteristic of the separation of two adjacent peaks. It may be expressed according to the equation:

$$R_{AB} = 2 \frac{|d_R(B) - d_R(A)|}{|w(B) + w(A)|}$$

where  $R_{AB}$  is the resolution,  $d_R(A)$  and  $d_R(B)$  are the retention distances (time or volume) of each eluted component A and B, and  $w(A)$  and  $w(B)$  are the respective widths of each peak at its base. **GB**: The peak width is the segment of the *peak base* that bisects the *peak height* and terminates at the intersections with the two limbs of the peak projected onto the axis representing time or volume if the *base line* is not parallel to this axis.

**Response time**: Time taken for an instrument to respond to a rapid change in value of the air quality characteristic. It consists of two major parts: a) *Lag time*, the time taken to reach 10% of the final change in instrument reading; b) *rise time (fall time)*, the time taken to pass from 10% to 90% of the final change in instrument reading. For instruments where transient oscillations occur in the approach to the final instrument reading, the rise time is considered to be the time taken for the oscillations to fall to less than 10% of the final change in instrument reading.

**Retention efficiency (in particle separation)**: The ratio of the quantity of particles retained by a separator to the quantity entering it (generally expressed as a percentage).

**Retention time in gas chromatography**: The time between the beginning of the injection of a sample and the moment where there is emergence of the peak maximum of a stated component. This time is quite reproducible with a given pure component when the flows, temperature, etc., are carefully controlled.

**Ringelmann chart**: A chart which has been used in air pollution evaluation for assigning the degree of blackness of smoke emanating from a source. The observer compares the shades of grey (white to black) with a series of shade diagrams formed by horizontal and vertical black grid lines on a white background. A corresponding number, the Ringelmann number, is then assigned to describe the best match; numbers range from 0 (white) to 5 (black). This method of pollution evaluation, although relevant to the enforcement of legislation still in force in many countries, is not recommended for use today since more quantitative indicators of the efficiency of the combustion are now available.

**Rotometer**: A device, based on Stokes law, for measuring rate of fluid flow. It is a tapered vertical tube having a circular cross section in which a float moves in a vertical path to a height dependent upon the rate of fluid flow upward through the tube.

*Sample, air:* A quantity of air (sometimes of known volume), which is assumed to be representative of the air mass under investigation, and which is examined for air quality characteristics.

*Sample line:* Line provided to remove a representative sample of the gas to be analysed and to conduct it to the sample point. It may include devices such as filters, dryers, or condensers (primary and secondary treatments of gas) which are necessary to prepare the sample for analysis.

*Sample point:* Point in the gas analysis installation beyond which it is assumed that no alteration of the sample occurs and the sample can be considered representative.

*Sample probe:* Device inserted into the gas to be sampled and to which is connected a sample line or a container for collecting the sample.

*Sampler:* Same as *collector*.

*Sampler, dichotomous:* Device for dividing a polydispersed aerosol particle population into two size fractions during sampling. The fractionation is based on the momentum differences of the particles which allow the larger particles to pass through a zone of stagnant gas.

*Sampling, continuous:* Sampling, without interruptions, throughout an operation or for a predetermined time.

*Sampling, cryogenic:* The collection of trace compounds from gaseous media by co-condensation with a major constituent (e.g., water vapour, CO<sub>2</sub>, N<sub>2</sub>, Ar) of the matrix.

*Sampling, discontinuous:* Sampling in which the sample flow is periodically interrupted but not necessarily at equal time intervals.

*Sampling, grab:* The taking of a sample (often in an evacuated bulb) in a very short time; preferred terms are *instantaneous sampling* or *spot sampling*.

*Sampling, sequential:* Repetitive sampling from the same gas to be analysed or from several gases to be analysed successively.

*Sampling train:* The complete assemblage of equipment necessary to sample atmospheres.

*Sanitary land fill:* An engineered burial of refuse. The refuse is dumped into trenches and compacted by bulldozer, where, it is hoped, aerobic metabolism by microorganisms decomposes the organic matter to stable compounds (H<sub>2</sub>O, CO<sub>2</sub>, etc.). Moisture is essential for the biological degradation and groundwater assists the process except when it fills air voids and prevents the transport of oxygen to the refuse. Land fills of unsatisfactory design can be major sources of air, water and soil pollution.

*Saturation vapour pressure:* The pressure exerted by a pure substance (at a given temperature) in a system containing only the vapour and condensed phase (liquid or solid) of the substance.

*Scale:* In meteorology, the size of the system. Microscale processes are the subject of micrometeorology, synoptic scale processes are studied in synoptic meteorology, etc.

*Scale height:* Distance given by  $kT/mg$  where  $k$  is the Boltzmann constant,  $T$  the temperature (K),  $m$  is the molecular mass, and  $g$  is the acceleration due to gravity. The scale height is equal to twice the distance through which a particle having kinetic energy  $kT/2$  in the vertical direction can rise against the force of gravity.

*Scanning in mass spectrometry:* Variation of one or more operating parameters (electric, magnetic, etc.) of a spectrometer which makes it possible to cause the appearance, in the ion collector, of a succession of ions with increasing or decreasing mass to charge ratio.

*Scattering (light):* An interaction of light with an object that causes the light to be redirected in its path.

*Scattering angle:* The angle between the direction of propagation of the scattered and incident (or transmitted) light.

*Scattering cross section ( $\sigma_{\text{scat}}$ ):* The scattering coefficient per particle, (cm<sup>2</sup>/particle);  $b_{\text{scat}} = n\sigma_{\text{scat}}$  where  $n$  is the number concentration of particles (particles/cm<sup>3</sup>) and  $\sigma_{\text{scat}}$  is the scattering cross section.  $b_{\text{scat}}$ , the scattering component of extinction due to gas and particles, is measured in the atmosphere using a

nephelometer. For a homogeneous atmosphere it is related in theory to the meteorological range ( $L_v$ ):  $L_v = 3.9/b_{\text{scat}}$ ;  $b_{\text{scat}}$  and  $b_{\text{abs}}$  represent the scattering and absorption coefficients per unit length for a light beam (of path length  $L$ ) which has a spectral radiance (intensity)  $I_0$  incident on a sample of air and  $I$  is the transmitted spectral radiance (intensity),  $\ln(I_0/I) = L(b_{\text{scat}} + b_{\text{abs}})$ .

*Scavenging*: The removal of pollutants from the atmosphere by natural processes, including scavenging by cloud water, rainout, and washout. This type of removal process is termed *precipitation scavenging*. Scavenging of airborne pollutants at surfaces of plant, soil, etc., is termed *dry deposition*.

*Scrubber*: An apparatus used in sampling and in flue gas cleaning. The gas is passed through a space containing wetted "packing" or spray. In general, particles are collected in scrubbers by one or a combination of the following: impingement of particles on liquid medium; diffusion of the particles onto liquid medium; condensation of liquid medium vapours on the particles; partitioning of the gas into extremely small elements to allow collection of the particles by Brownian diffusion and gravitation settling on the gas-liquid interface. The devices include spray towers, jet scrubbers, Venturi scrubbers, cyclonic scrubbers, inertial scrubbers, mechanical scrubbers, and packed scrubbers. Normally the gas flow in the scrubber is counter to the liquid flow. Efficient scrubbers will collect particles as small as 1 to 2  $\mu\text{m}$  in diameter.

*Scrubbing*: A process used in gas sampling or gas cleaning in which components in the gas stream are removed by contact with a liquid surface or a wetted packing, on spray drops, droplets, or in a bubbler, etc.

*Secondary pollution (emissions)*: The products of the primary pollutants which form through photochemical and thermal reactions in the atmosphere ( $\text{O}_3$ , peroxyacetyl nitrate, etc.).

*Sedimentation*: In the atmospheric sciences, the process of removal of an air borne particle from the atmosphere due to the effect of gravity.

*Selectivity*: The degree of independence of a measured quantity ( $X$ ) of an air quality characteristic  $C_a$  from interferants ( $C_1, C_2, \dots, C_n$ ). A first order measure of the selectivity ( $I_i$ ) is given by the relation:

$$I_i = \frac{\frac{\delta g(C_a, C_1, C_2, \dots, C_n)}{\delta C_a}}{\frac{\delta g(C_a, C_1, C_2, \dots, C_n)}{\delta C_i}}$$

with  $i = 1, 2, \dots, n$ , and  $X$  is defined by the regression function:

$$X = g(C_a) \Big|_{C_i = \text{constant}}$$

$I_i$  may depend on the value of the air quality characteristic. See also *calibration function*.

*Sensitivity*: The rate of change of instrument reading with respect to the change of the value of the air quality characteristic. See also *calibration function*.

*Settling chamber*: Chamber designed to reduce the velocity of gases in order to permit the settling out of fly ash. It may be either part of, adjacent to, or external to an incinerator.

*Settling velocity*: The terminal rate of fall of a particle through a fluid as induced by gravity or other external force.

*Sink*: In atmospheric chemistry, the sink is the receptor for material which is removed from the atmosphere. Because of long range transport of many pollutants such as  $\text{SO}_2$ , sulfuric acid and its salts, the sink region can be many hundreds of kilometers from the source region of the pollutants.

*Sintering*: The process by which fly ash produced in combustion of fuels such as coal, is baked (sintered) at a very high temperature. The sintered material is used in the manufacture of cinder blocks and other ceramic products. This term is also relevant to the enrichment of low grade ores and preparation of the charge for, e.g., a blast furnace. The sinter plant may be a significant source of pollution while serving to aid in the abatement of pollution for the blast furnace. **GB**: Coalescence of solid particles. Catalysts often suffer during use from a gradual increase in the average size of the crystallites or growth of the primary particles. This is

usually called sintering.

**Smog:** The term originated in Great Britain as a popular derivation of "smoke-fog" and appears to have been in common use before World War I. It originally referred to the heavy pollution derived largely from coal burning (largely smoke filled air, rich in sulfur dioxide), and it probably was largely a reducing atmosphere. More common today in cities is an oxidising atmosphere which contains ozone and other oxidants; see *photochemical smog*.

**Smog alert:** Conditions indicated by meteorological forecasts, air sampling, etc., where authorities responsible for air pollution control in a given area recommend or impose reduction of pollutant output by industry and other sources which contribute to the smog development. Alert levels of gaseous pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, ozone) are considered indicative of an approach to danger to public health. Usually several levels of alert with increasing hazard are used. For example, Los Angeles County Air Pollution Control District, uses an initial warning level, a second signal for curtailment of certain significant sources, and a third level at which emergency action must be taken.

**Smog chamber:** A large confined volume in which sunlight or simulated sunlight is allowed to irradiate air mixtures of atmospheric trace gases (hydrocarbons, nitrogen oxides, sulfur dioxide, etc.) which undergo oxidation. In theory these chambers allow the controlled study of complex reactions which occur in the atmosphere. However, ill-defined wall reactions which generate some molecular and radical species (e.g., HONO, CH<sub>2</sub>O, HO-radicals, etc.) and remove certain products (H<sub>2</sub>O<sub>2</sub>, HNO<sub>3</sub>, etc.), the use of reactant concentrations well above those in the atmosphere, ill-defined light intensities and wavelength distribution within the chamber, and other factors peculiar to chamber experiments require that caution be exercised in the extrapolation of results obtained from them to atmospheric systems.

**Smog index:** A mathematical correlation between smog and meteorological and/or pollutant concentrations associated with it. These are qualitative indices which are sometimes used in some urban communities to predict the degree of the air pollution which is expected for the coming day. See *smog alert*.

**Smoke:** A visible aerosol made up of small gas-borne particles resulting from the incomplete combustion of organic matter. It consists of carbon, carbon-rich products and all other dispersible product particles from the incomplete combustion. This does not include steam (condensed water vapour).

**Smoke abatement:** Legal measures which a control agency of a community may take to enforce laws and regulations concerning smoke emission.

**Smoke alarm:** An instrument which can provide an objective method of continuous measurement of the smoke density. Such devices are often depend upon the attenuation of light, and they can actuate an alarm when the attenuation exceeds some predetermined amount.

**Smokestack:** A chimney which carries the products of combustion away from a combustion chamber.

**Smuts:** Agglomerates of soot that become detached from the wall of a chimney and are swept out by the flue gas and then fall in the vicinity of the stack.

**Soiling:** Visible damage to materials by deposition of air pollutants.

**Sol: (GB)** A fluid colloidal system of two or more components, e.g. a protein sol, a gold sol, an emulsion, a surfactant solution above the critical micelle concentration.

**Solar radiation:** The electromagnetic radiation emitted by the sun. The total range of wavelengths of light emitted by the sun (99.9% in the range from 150 to 4000 nm) is filtered on entering the earth's atmosphere, largely through the absorption by oxygen, ozone, water vapour, and carbon dioxide. Near sea level only light of wavelengths longer than about 290 nm is present. The light from 290-400 nm is effective in inducing important photochemical processes since absorption by the important trace gases, ozone, nitrogen dioxide, aldehydes, ketones, etc., is significant in this region.

**Solubility:** The maximum amount of material, pure solid, liquid, or gaseous compound (grams, mol, etc.) which will dissolve at equilibrium in a given amount of solvent (100 g, 1 kg, 1 litre of solution, etc.) at a given temperature. The system is at equilibrium (at a fixed temperature) when the solution phase as well as the solid, liquid, or gas phase remain in contact indefinitely without further net change in amount of either phase. The solubility of gases in water is often considered in terms of *Henry's law*.

**Solution:** A homogeneous mixture of two or more elements or compounds. The term may be applied to



mixtures of solids as well as liquids, but unless stated otherwise, solution normally refers to a liquid medium (e.g.,  $\text{H}_2\text{SO}_4$  in water). **GB:** A homogeneous liquid or solid phase containing more than one substance, when for convenience one of the substances, which is called the solvent and may itself be a mixture, is treated differently from the other substances, which are called solutes.

**Soot:** Aggregations of black carbonaceous particles formed during incomplete combustion and which are deposited before being emitted from a chimney.

**Sorption:** Process by which a substance (sorbate) is sorbed (adsorbed or absorbed) on or in another substance (sorber); see also *absorption, adsorption, desorption*. **GB:** It is sometimes difficult or impossible to discriminate experimentally between adsorption and absorption: in such cases it is convenient to use the non-committal term *sorption* (together with its derived terms, *sorbent, sorbate, sorptive*).

**Source:** In atmospheric chemistry, the place, places, or group of sites or areas where a pollutant is released into the atmosphere. Point sources, elevated sources, area sources, multiple sources are often identified.

**Span:** Difference between the instrument readings for a stated value of air quality characteristic and a zero sample. By convention, this value of air quality characteristic is selected to be 95% of the upper limit of measurement.

**Species:** In chemistry, a given kind of atom, molecule or radical which has a characteristic chemical structure and composition. **GB:** A chemical species is a set of chemically identical atomic or molecular structural units in a solid array or of chemically identical molecular entities that can explore the same set of molecular energy levels on the time scale of the experiment.

**Specific gravity:** See *relative density*.

**Spectrometry, optical (in trace component analysis of air):** Methods of identification of substances and determination of their concentration based upon the measurement of light transmittance at selected wavelengths or bands of wavelengths; see also *mass spectrometry*.

**Spheradiance, spectral:** Alternate term suggested for *Actinic flux*.

**Spectrophotometry:** Methods using a photometer to measure light intensity as a function of wavelength.

**Stability, static:** In meteorology, the stability of the atmosphere in the vertical direction, to vertical displacements. If  $\Gamma$  is the dry adiabatic lapse rate, dry air is stable if the lapse rate ( $-dT/dz$ )  $< \Gamma$ , unstable if ( $-dT/dz$ )  $> \Gamma$ , and neutral if  $-(dT/dz) = \Gamma$ ; see *lapse rate* and *inversion*.

**Stack:** See chimney.

**Stack gas:** Gaseous waste products discharged to the atmosphere through a stack.

**Stack height selection:** The degree of dispersion of the stack effluent increases with the height of the stack. The maximum ground level concentration of pollutants and the point from the stack at which this occurs are complex functions of the wind turbulence and other meteorological factors as well as stack height. There are physical and practical limitations which control the choice of stack height: cost, air traffic hazards, aesthetic considerations, aerodynamic factors, vibration, materials, etc. The tallest stack now in existence (1990) is that of the International Nickel Company of Canada (Sudbury, Ontario) which is 379.7 m tall, with a diameter of 35.5 m at the base and 15.8 m at the top. It weighs  $3.901 \times 10^7$  kg. In recent years there has been less reliance on tall stacks for dispersing stack effluent and more concern for pollutant removal either before, during, or after combustion. This has been brought about through the realization that transport of certain pollutants such as  $\text{SO}_2$  can occur over large distances and introduce problems such as acid deposition at receptor sites many hundreds of kilometers from the source.

**Stack sampling:** Collection of representative gaseous and particulate samples of matter flowing through a duct or stack. Acceptable performance should indicate a collection efficiency of  $95 \pm 5$  percent. Samples should be taken under isokinetic conditions to obtain an accurate representation of the particle size distribution in the effluent.

**Stagnant inversion:** See *inversion, temperature*.

**Standard:** An exact value, or a concept, that has been established by authority or agreement, to serve as a model or rule in the measurement of a quantity or in the establishment of a practice or procedure. In air

pollutant analysis, standard reference gases, liquids, or solids are used to calibrate equipment. The concentrations of standards specified by a government agency or private laboratory must be based upon accurate measurement techniques which are verifiable through cross checks and the use of unambiguous methods.

*Standard conditions for gases:* Sometimes indicated with the abbreviation, STP. Temperature, 273.15 K (0 °C) and pressure of  $10^5$  pascals. IUPAC recommends that the former use of the pressure of 1 atm as standard pressure (equivalent to  $1.01325 \times 10^5$  Pa) should be discontinued.

*Standard deviation,  $\sigma$ :* A useful measure of the precision of the average of a series of  $n$  measurements ( $x_i$ ) of the same quantity; when  $n$  is large,  $\sigma$  is given by:

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{(n-1)}}$$

It is usual to report the "error limits" on an average estimate of a given quantity as  $\pm 1\sigma$  (67% confidence limits),  $\pm 2\sigma$  (95% confidence limits) or  $\pm 3\sigma$  (99.7% confidence limits). For large numbers of measurements of a quantity which contain only random errors, the ranges represented by  $\bar{x} \pm 1\sigma$ ,  $\bar{x} \pm 2\sigma$ , and  $\bar{x} \pm 3\sigma$  are those for which one expects the true value of  $x$  to lie with 67, 95 and 99.7% confidence, respectively. For a small number of measurements of  $x$  ( $n$  is small), the term  $(n-1)$ , the degrees of freedom in the above relation, must be replaced by an appropriate (somewhat smaller) value. For applications involving small sample theory, a reference book on statistics should be consulted.

*Stationary phase in gas chromatography:* Solid or liquid which has reversible sorption properties, for the components to be analysed. **GB:** The non-mobile phase in the chromatographic bed, on which the separation depends. For example, in gas-solid chromatography and liquid-solid chromatography the active solid, and in gas-liquid and liquid-liquid chromatography the liquid, but not the solid support.

*Stratopause:* That region of the atmosphere which lies between the stratosphere and the mesosphere and in which a maximum in the temperature occurs.

*Steady state:* A term used in reaction kinetics to describe the near constant (steady) concentration of reactive intermediate species in a reacting system when it is formed at a rate which is approximately equal to its rate of removal. In the atmosphere very reactive transient species such as  $O(^1D)$  and HO have very short lifetimes and achieve a steady state in a very short time. Longer lived transient radicals (e.g., organylperoxyl radicals and  $NO_3$ ) and reactive molecules (e.g.,  $N_2O_5$ ) achieve a steady state much more slowly (or never achieve one), since the rates of their formation and/or destruction may vary significantly during the lifetime of the species. The steady state concentration of a highly reactive species does adjust quickly to changes in the conditions such as the reactant concentrations, and, if the reactions forming or destroying the intermediate have a photochemical component, the actinic flux. In this case when the nearly constant concentration of the reactive transient is achieved, the system is said to be in a *photostationary state*.

*Steric factor:* Term ( $p$ ) used in the older literature to describe the make up of the preexponential factor ( $A$ ) in the Arrhenius equation for the rate coefficient:  $A = pz$ , where  $z$  is the collision number and  $p$  represents the probability of correct orientation for reaction upon collision between two reactants.

*Stochastic sampling:* Random sampling.

*Stoichiometric:* Involving chemical combination in simple integral ratios. Characterized by having no excess of reactants or products over that required to satisfy the balanced chemical equation representing the given chemical reaction.

*Stoker:* A machine for feeding coal into a furnace, and supporting it there during combustion.

*Stokes law:*  $F = 6\pi\eta rv$ , where  $F$  is the force exerted on a sphere of radius  $r$  which is moving through a fluid of viscosity  $\eta$  with a relative velocity  $v$ ; this equation holds at low velocities which are free from turbulence (called the Stokes region).

*Stokes number ( $St$ ):* Sometimes referred to as the inertial parameter; it is an index of the impactability of an aerosol particle. It is defined by the equation:  $St = 2\tau(V_1 - v_1)D_p$  where  $D_p$  is the diameter of a small drop,  $V_1 - v_1$  is the difference in fall velocities of the drop and aerosol particles, and  $\tau$  is the characteristic relaxation time of a particle.

**Storage temperature, minimum:** The temperature below which the indicated uncertainty of the composition of the mixture may be altered, for example, for one of the following reasons: sorption of one or more components by the walls of the gas cylinder may occur; condensation of one or more components may occur.

**Storage temperature, maximum:** The temperature above which the indicated uncertainty of the composition of a standard substance or mixture may be altered because of physical, chemical, or physico-chemical reactions of the components of the mixture with each other or decompositions or reactions catalyzed at the wall of the gas cylinder.

**STP:** Abbreviation for standard temperature (273.15 K or 0 °C) and pressure ( $10^5$  Pa); usually employed in reporting gas volumes. Note that flow meters calibrated in standard gas volumes per unit time often refer to volumes at 25 °C, not 0 °C. See also *standard conditions for gases*.

**Stratosphere:** The atmospheric shell lying just above the *troposphere* which is characterized by an increasing temperature with altitude. The stratosphere begins at the tropopause (about 10-15 km height) and extends to a height of about 50 km, where the lapse rate changes sign at the stratopause and the beginning of the mesosphere.

**Sulfur dioxide ( $SO_2$ ):** A major oxidation product of sulfur-containing compounds in fuels and the major sulfur species emitted from power plants, furnaces, and other combustion sources. It is oxidized eventually to sulfuric acid and its salts in the atmosphere by reaction with HO-radicals in the gas phase, and more rapidly in cloud-water, rain, and in ground water, where it exists largely as  $HSO_3^-$  ion, by reaction with dissolved  $H_2O_2$ ,  $O_3$ , and other oxidizing agents.

**Supersaturation:** a) *In chemistry*, an unstable system which has a greater concentration of a material in solution than would exist at equilibrium is said to be supersaturated. b) *In meteorology*, supersaturation of an air mass with respect to  $H_2O$  vapour is of special interest. It is the saturation ratio minus one, or the percent supersaturation is the percent relative humidity minus 100.

**Suspended matter:** All particulate material which persists in the atmosphere or in a flue gas stream for lengthy periods because the particles are too small in size to have an appreciable falling velocity.

**Synoptic scale:** In meteorology, the size or scale of ordinary weather systems or cyclones; typically 1000 km horizontally.

**Temperature, thermodynamic:** The temperature measured on the thermodynamic scale, designated in kelvin (K); the term "absolute temperature" common in the older literature, is not recommended. Temperature ( $\theta$ ) measured on the Celsius scale is related to the thermodynamic temperature ( $T$ , K) by:  $\theta/^\circ\text{C} = T/\text{K} - 273.15$ .

**Thermosphere:** Atmospheric shell extending from the top of the mesosphere to outer space. It is a region of more or less steadily increasing temperature with height, starting at 70 or 80 km. It includes the exosphere and most or all of the ionosphere (not the D region).

**Titration:** The process of addition of a standard solution to a fixed volume of unknown solution usually from a buret, until the amount added is chemically equivalent to the substance being measured. This point is called the end point, which is often detected for solution titrations by an indicator that senses a minuscule excess of the standard solution. E.g., a standard base solution may be used to titrate the amount of acid in a sample of rain-water. Gas-phase titrations are also made with certain substances. E.g., the concentration of  $O_3$  in a gaseous flow may be titrated by using a measured but variable flow of a standard mixture of NO; the maximum in the measured intensity of the chemiluminescence of the excited  $NO_2^*$  formed ( $O_3 + NO \rightarrow NO_2^* + O_2$ ;  $NO_2^* \rightarrow NO_2 + h\nu$ ) is used to determine the end point.

**Titrimetric methods:** A class of volumetric analytical methods employing titration as the basis of quantitative measurement.

**Toxicity:** The quality of being poisonous. It may be expressed as a fraction indicating the ratio of the smallest mass of the material which has some specified probability (often 50%) of causing death of some specific animal to the mass of the animal.

**Tracer:** A foreign substance mixed with or attached to a given substance to enable the distribution or location of the latter to be determined subsequently. There are several types of tracers which are used: a) *A physical tracer* is one that is attached by physical means to the object being traced; b) *A chemical tracer* is a chemical with properties similar to those of the substance being traced with which it is mixed homogeneously; c) *An isotopic tracer* is a unique isotope, either radioactive or an enriched, uncommon stable

isotope, of the element to be traced; *d*) A *radioactive tracer* is a physical or chemical tracer having radioactivity as its distinctive property which allows detection at small concentrations and hence after large transport distances. The composition of aerosols in the troposphere has been used as a qualitative tracer of air masses. The elemental analyses (determined by neutron activation, X-ray fluorescence, etc.) of the aerosols transported from various sources or source regions sometimes have characteristic patterns which are used to define qualitatively the origin of tropospheric aerosols collected in other geographical regions.

*Transfer line*: Line provided to carry the sample to be analysed from the sample point to the analytical unit without altering the composition of the sample.

*Transition state*: (GB) In theories describing *elementary reactions* it is assumed that there is a transition state of more positive molar Gibbs energy between the reactants and the products through which an assembly of atoms (initially composing the *molecular entities* of the reactants) must pass on going from reactants to products in either direction. In the formalism of transition state theory the transition state of an elementary reaction is that set of states (each characterized by its own geometry and energy) such that an assembly of atoms, when randomly placed there, would have an equal probability of forming the reactants or of forming the products of that elementary reaction. This set of states is characterized by  $q_{\ddagger}$ , the partition function for the transition state. The assembly of atoms at the transition state may be called an activated complex.

*Transmittance*: The ratio of the transmitted spectral radiance (intensity),  $I_t$ , of monochromatic light (single wavelength or small band of wavelengths) to that of the incident spectral radiance (intensity),  $I_0$ :  $I_t/I_0$ .

*Troe expression*: A semi-empirical description of the rate coefficient for a specific three body reaction [e.g.,  $\text{HO} + \text{NO}_2 (+\text{M}) \rightarrow \text{HONO}_2 (+\text{M})$ ] which represents well its pressure and temperature dependence in the region of transition between second and third order kinetics.

*Troposphere*: The lowest layer of the atmosphere, ranging from the ground to the base of the stratosphere (tropopause) at 10-15 km of altitude depending on the latitude and meteorological conditions. About 70% of the mass of the atmosphere is in the troposphere. This is where most of the weather features occur and where the chemistry of the reactive anthropogenic species released into the atmosphere takes place.

*Tropopause*: The region of the atmosphere which joins the troposphere and stratosphere, and where the decreasing temperature with altitude, characteristic of the troposphere ceases, and the temperature increase with height which is characteristic of the stratosphere begins.

*Turbidity*: Term used to indicate the degree of cloudiness of water samples which is caused primarily by the presence of colloidal matter. One unit of turbidity is defined as optical density of 0.001 (yellow light, 580 nm) per cm of depth.

*Turbulence*: Atmospheric eddies, mechanical or thermal, which are produced primarily by shearing stress or by convection. Atmospheric turbulence is primarily responsible for the dilution and mixing of atmospheric pollutants. Turbulent fluctuation in stable air are mainly of high frequency with typical periods of seconds (mechanical turbulence). The fluctuation often constitute major deformations of flow and are capable of transporting momentum, energy, and suspended matter at rates far in excess of the rate of transport by molecular diffusion and conduction in a nonturbulent or laminar flow.

*Undetermined components*: Components of the sample, the concentrations of which are not measured during the analysis.

*Vacuum line*: Gas-tight system of tubing equipped with accessories such as valves, manometers, pumps, etc., which enable a gas to be transported from one point to another.

*Variance*: A quantity, equal to the square of the standard deviation ( $\sigma^2$ ), used to measure precision of an average of a number of measurements of a quantity; see *standard deviation*.

*Visibility*: Defined as the greatest distance at which a black object of suitable dimensions can be seen and recognized against the horizon sky, or, in the case of night observations, could be seen and recognized if the general illumination were raised to the normal daylight level. The criterion of recognizing the object, not just seeing the object without recognition, is used. Transmissometers, telephotometers, and sun photometers are devices used to measure the degree of transmission of light. Nephelometers (integrating) are used to measure visibility by way of the light scattering from aerosols in the air mass.

*Volume measuring device, gases*: Several different devices exist with which gas volumes are measured: *a*) *Dry test meter*: A device which consists of bellows and valves. Gas fills the bellows to a predetermined volume;

this volume of gas is then released, and the bellows return to their original position. The cycle is repeated and the cyclic motion activates an indicator. *b) Wet test meter:* A device consisting of a cylindrical chamber divided into compartments. The cylinder is partially submerged in a fluid, usually water, and the gas to be measured enters below the water line. As the gas flows into a compartment the fluid is displaced and the cylinder turns. When one compartment has been filled the next one fills, and a continuous rotary motion of the cylinder results. The rotary motion is indicated on a dial.

*Wash out:* The removal from the atmosphere of gases and sometimes particles by their solution in or attachment to rain-drops as they fall.

*Wet bulb temperature:* In psychrometry, the temperature of the sensor or the bulb of a thermometer in which a constantly renewed film of water is evaporating. The temperature of the water used to renew the film must be at the temperature of the gas. See *psychrometry*.

*Wind rose:* A diagram designed to show the distribution of wind direction experienced at a given location over a considerable period of time. Usually shown in polar coordinates (distance from the origin being proportional to the probability of the wind direction being at the given angle usually measured from the north). Similar diagrams are sometimes used to summarize the average concentrations of a given pollutant seen over a considerable period of time as a function of direction from a given site (sometimes called a *Pollution rose*).

*Zero gas or zero sample:* Substance or mixture of substances resembling, as closely as possible, the matrix of the actual air sample to be measured, but characterized by a value of the air quality characteristic which is not detectable by the method used.