This document sets forth background materials on the scientific research supporting examinations as conducted by the forensic laboratories at the Department of Justice. It also includes a discussion of significant policy matters. This document is provided to assist a public review and comment process of the related Proposed Uniform Language for Testimony and Reports (posted separately). It is not intended to, does not, and may not be relied upon to create any rights, substantive or procedural, enforceable by law by any party in any matter, civil or criminal, nor does it place any limitation on otherwise lawful investigative and litigative prerogatives of the Department.

SUPPORTING DOCUMENTATION FOR DEPARTMENT OF JUSTICE PROPOSED UNIFORM LANGUAGE FOR TESTIMONY AND REPORTS FOR THE GENERAL CHEMISTRY DISCIPLINE

Background

Chemistry is the study of matter and its changes. Forensic chemistry is the application of chemistry for legal proceedings; it involves determining the chemical identity and characteristics of substances and performing chemical comparisons of substances.

General chemistry forensic analysis provides analyses of unknown substances to determine chemical identity, to determine chemical characteristics and to perform chemical comparisons. Substances analyzed include chemicals commonly associated with bank dye packs, controlled substances, pharmaceuticals, pepper sprays, inks, lubricants, and general unknowns.

Principles of General Chemistry Examinations

General chemical forensic analysis permits a broad array of analyses based upon well-established chemical and instrumental techniques that are universally accepted in the scientific community. These techniques are not limited to forensic science and are routinely used in a variety of industries as well as academia. While instrumentation has advanced to become more sensitive with shorter analysis times, the same basic methods and theories have been employed for decades. These chemical and instrumental techniques provide reliable data that are dependent upon the chemical properties of the substance that was analyzed. As such, an examiner is typically able to interpret the data to deduce the chemical identity of the substance. On occasion, the data does not support a chemical identification; however, the data may allow the examiner to group the substance within a class of chemicals or products.

General Chemistry Processes

There are different methodologies and processes for conducting a general chemistry examination. The Department shares information regarding some appropriate processes below. The Department does not suggest that the processes outlined here are the only valid or appropriate processes.

Common general chemistry examinations include:

- Drug analyses (including weight, volume, and purity determination): analyses of powders, liquids, tablets, and other items to detect the presence, weight, volume, and/or purity of controlled and non-controlled substances.

- Drug residue analyses: analyses of items to detect the presence of trace amounts of controlled substances.

- Bank dye analyses: analyses of stained items (*e.g*., clothing, currency) to detect the presence of chemicals found in bank security devices.

- Lubricant analyses: analyses of items to detect the presence of lubricants (often in the context of cases involving sexual assaults, drug trafficking, or vehicular homicide).

- General unknown analyses: analyses of substances which are of indeterminate origin or which cannot be readily classified among the types of substances routinely examined.

Examinations performed to determine the presence or absence of specific analytes are referred to as targeted examinations. Examinations performed on general unknown substances are referred to as non-targeted examinations. Each examination is conducted in accordance with the laboratory's quality assurance system. When possible, orthogonal techniques (*i.e*., two or more techniques predicated on different chemical principles) can be employed in order to reach a determination.

The below examination processes involving controlled substances adhere to published recommendations of the Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG).[1] Examination processes involving analysis of unknown samples related to chemical terrorism investigations adhere to published recommendations of the Scientific Working Group on the Forensic Analysis of Chemical, Biological, Radiological and Nuclear Terrorism (SWGCBRN).[2]

Upon receipt of a case, the examiner evaluates the evidence and determines the standard operating procedure(s) (SOPs) to apply. Typically, the SOP(s) employed will involve performing multiple techniques of increasing sensitivity and selectivity. These are classified as screening or confirmation techniques for targeted examinations. For

[1] Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG), *Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG) Recommendations,* Version 7.0 (August 14, 2014).

[2] Magnuson ML, Satzger RD, *et. al.*, Guidelines for the identification of unknown samples for laboratories performing forensic analyses for chemical terrorism, J. Forensic Sci., 2012 May; 57(3): 636-42.

non-targeted examinations, the training and experience of the examiner helps dictate the initial techniques to be employed. When the weight, volume, or purity of a substance needs to be reported, a quantitative technique will be used.

Screening Techniques

Targeted examinations typically begin with a screening technique to test for the presence or absence of a specific analyte (*i.e.*, the substance of interest), or to indicate when further testing may be warranted. The screening technique(s) is selected based on the target analyte and the nature of the specimen. Screening techniques can include, but are not limited to:

- Gas Chromatography (GC)
- Liquid Chromatography (LC)
- Capillary Electrophoresis (CE)
- Thin Layer Chromatography (TLC)
- Chemical spot tests
- Direct Analysis in Real Time/Time-of-Flight Mass Spectrometry (DART/TOFMS)
- Ion Mobility Spectrometry (IMS)
- Ultraviolet-Visible Spectrophotometry (UV-Vis)
- Fourier Transform Infrared Spectroscopy (FTIR)

Confirmation Techniques

A positive screening result is confirmed by performing orthogonal analyses (when possible). The confirmatory test(s) for a target analyte is typically more specific than the screening technique. When possible, a structural elucidation technique (*i.e.*, a technique used to determine what elements are present and how they are arranged) is used. Confirmatory techniques can include, but are not limited to:

- Gas Chromatography/Mass Spectrometry (GC/MS)
- Liquid Chromatography/Mass Spectrometry (LC/MS)
- Fourier-Transform Infrared Spectroscopy (FTIR)
- Nuclear Magnetic Resonance Spectroscopy (NMR)
- X-Ray Diffractometry (XRD)
- X-Ray Fluorescence Spectrometry (XRF)
- Scanning Electron Microscopy/Energy Dispersive X-ray Spectrometry (SEM/EDS)

Non-Targeted Examinations

For non-targeted examinations (*i.e.*, examinations of general unknown substances), an appropriate analytical scheme is employed to chemically classify or identify the questioned substance. Examinations of unknown substances are dynamic in nature. The applied techniques and the sequence of examinations follow from the results of the most recently performed technique. The techniques used in non-targeted examinations are the same as those employed in targeted examinations. Examination of a general unknown substance becomes a targeted examination when a specific analyte is suspected to be present.

Quantitative Techniques

For the general chemistry discipline, quantitative measurements can include determining weight, volume, and purity levels of a substance. The weight of a substance is determined using a calibrated, analytical balance and is reported with an estimate of measurement uncertainty at a specified confidence level. Volume of a substance is determined using class A volumetric glassware, or calibrated instruments, and is reported with an estimate of measurement uncertainty at a specified confidence level. In instances where both the weight and volume of a substance are reported, an associated estimated measurement uncertainty and confidence level is only necessary for one of the reported measurements (unless the weight and volume are being used in combination to calculate and report the density of the substance). The purity of a substance is determined using a validated method with comparison to verified reference materials and is reported with an estimate of measurement uncertainty at a specified confidence level.

Measurement uncertainties are estimated according to a SOP, which can be derived from the Guide to the Expression of Uncertainty in Measurement (GUM),[3] a widely accepted method for determining measurement uncertainty, as well as the NIST standard operating procedure, accreditation policy, and other guidance documents.[4]

Conclusions

Once the examiner reaches a conclusion(s), criteria specified in the SOP(s) are used to report and testify to the conclusion(s). Typical conclusions include:

(a) Identification
(b) Consistent with
(c) Not identified (Negative)
(d) Cannot be differentiated
(e) Can be excluded
(f) Inconclusive
(g) Quantitative results
(h) Sampling inferences

[3] Joint Committee for Guides in Metrology, *Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement* (JCGM 100:2008 GUM 1995 with minor corrections) (1st ed. 2008).

[4] National Institute of Standards and Technology, *SOP 29- Standard Operating Procedure for the Assignment of Uncertainty*, (Gaithersburg, Maryland, February 2012), (http://www.nist.gov/pml/wmd/labmetrology/upload/SOP_29_20120229.pdf).; ASCLD/LAB-*International*, ASCLD/LAB Policy on Measurement Uncertainty, AL-PD-3060 Ver 1.0, May 1, 2013; ASCLD/LAB-*International*, ASCLD/LAB Policy on Measurement Traceability, AL-PD-3057 Ver 1.0, May 1, 2013.

(a) Identification

The examiner may report and testify to the identity of an analyte in a questioned sample when:

- Positive results have been obtained for an analyte within the questioned substance using orthogonal techniques, at least one of which was a structural elucidation technique;

- The pre-defined decision criteria set forth in the relevant SOP(s) were satisfied for each chemical analysis that gave a positive result; and

- The analysis included the use of negative and positive controls. If a positive control is unavailable, the analysis included either comparison to peer reviewed literature; structural elucidation of the material; or comparison to a reliable library result.

An example of an identification result is: "1-Methylaminoanthraquinone was identified on Item 1."

(b) Consistent With

The examiner may conclude that a questioned substance is consistent with a particular substance when:

- The analytical data does not support an identification of a specific chemical or product, but does provide reliable information to include a substance within a class of materials.

An example of a conclusion that a questioned substance is "consistent with" a particular substance is: "The bulk of Item 3 was consistent with an artificial sweetener."

(c) Not Identified / Negative Determination

The examiner may conclude that a particular substance is not identified on or in a questioned substance when:

- The results of the analytical examinations are negative for the substance or are below an administratively set limit.

An example of a conclusion that a questioned substance is negative for a particular substance is: "No controlled substances were identified within Item 1."

(d) Cannot Be Differentiated

In cases involving a comparison of samples, the examiner may reach a conclusion that the samples "cannot be differentiated" from one another when:

- The results do not show any relevant differences in chemical composition between or among the samples.

An example of a conclusion that a questioned substance "cannot be differentiated" from a particular substance is: "Colorants separated from the Item 2-1 ink could not be differentiated from colorants from either the Item 2-2 or Item 2-3 inks. Thus, the Item 2-1, 2-2, and 2-3 inks could have come from the same source."

(e) Can Be Differentiated or Can Be Excluded

In cases involving a comparison of samples, the examiner may reach a conclusion that the samples can be differentiated from one another or one sample "can be excluded" as being the source of another sample when:

- The results show relevant differences in analytical responses between or among the samples.

An example of a conclusion that a questioned substance "can be excluded" as being a particular substance is: "Propylene glycol and glycerin were identified within Item 10. This combination of chemicals was not identified within Item 11. Therefore, Item 11 can be excluded as the source of the stains on Item 10."

(f) Inconclusive

When none of the conclusions above can be reached, the examiner may issue an inconclusive result. The reason for the inconclusive result will be clearly stated in the report.

An example of an inconclusive result and the reason for the inconclusive result is: "Item 1 was heavily stained with a reddish-brown substance which subsequently limited the visual inspection of the item. No capsaicin or dihydrocapsaicin was identified on a sample taken from the stained area on Item 1. Although capsaicinoids were not identified within a sample taken from the Item 1 shirt, the heavy reddish-brown stains present on the item may have masked other stains and prevented them from being visualized. Therefore, no conclusion can be drawn as to the absence or presence of capsaicinoids on Item 1."

(g) Quantitative results

Weight

An examiner may report the weight of a substance. All reported weights will include the following (in instances where both the weight and volume of a substance are reported, an associated estimated measurement uncertainty and confidence level is only necessary for one of the reported measurements):

- Estimation of Measurement Uncertainty; and
- Confidence Level

An example of controlled substance weight result is: "The Item 3 plant material weighed 699.3 milligrams ± 0.4 milligrams (99.7% confidence level) and was identified as marijuana."

Volume

An examiner may report the volume of a substance. All reported volumes will include the following (in instances where both the weight and volume of a substance are reported, an associated estimated measurement uncertainty and confidence level is only necessary for one of the reported measurements):

- Estimation of Measurement Uncertainty; and
- Confidence Level

An example of controlled substance volume result is: "Item 1 consisted of 256 milliliters ± 3 milliliters (99.7% confidence level) and was identified as γ-butyrolactone (GBL)."

Purity

An examiner may report the purity of a substance. All reported purities will include the following:

- Estimation of Measurement Uncertainty; and
- Confidence Level

An example of controlled substance purity result is: "Cocaine was identified in Item 1 at a purity of 65 ± 9% (99.7% confidence level).

(h) Sampling Inferences

When an item submitted to a laboratory for testing consists of multiple, physically similar units the entirety of the units is referred to as the population. The examiner may remove a unit(s) from the population for testing in a manner that either allows for no inference or is a statistically-based sampling approach that allows for an inference to be made regarding the entire population. Sampling inferences will be reported unambiguously.

No inference

An example of sampling that provides no inference on the population is: "1 of 100 bags was analyzed and found to contain cocaine."

Inference on population

An example of sampling that provides an inference being made on the entire population is: "Powder from 28 packets was analyzed using a hypergeometric sampling plan resulting in a 95% confidence level that at least 90% of the packets contain heroin."

Policy Considerations

In 2006, Congress authorized the National Academy of Sciences (NAS) to conduct a study on forensic science and provide recommendations if warranted. The NAS convened the Committee on Identifying the Needs of the Forensic Science Community which published a 2009 report.[5] Although the report did not assess chemistry as a forensic discipline generally, it did assess the analysis of controlled substances, a forensic discipline based in forensic chemistry. In summary, the report concluded:

> The chemical foundations for the analysis of controlled substances are sound, and there exists an adequate understanding of the uncertainties and potential errors. SWGDRUG has established a fairly complete set of recommended practices. It also provides pointers to a number of guidelines for statistical sampling, both for illegal drugs per se (created by the European Network of Forensic Science Institutes) and for materials more generally (created by the American Society for Testing and Materials).[6]

The report's summary conclusions were based, in part, on the finding that:

> The analysis of controlled substances is a mature forensic science discipline and one of the areas with a strong scientific underpinning. The analytical methods used have been adopted from classical analytical chemistry, and there is broad agreement nationwide about best practices.[7]

---

[5] National Research Council, Committee on Identifying the Needs of the Forensic Science Community, *Strengthening Forensic Science in the United States: A Path Forward* (2009). National Academy Press: Washington, D.C. (http://www.nap.edu/catalog/12589.html).

[6] *Id*. at 135.

[7] *Id*. at 134 (citing to Smith, F and Siegel, J.A. (eds). (2004) *Handbook of Forensic Drug Analysis*. Burlington, MA: Academic Press).

Two items specifically addressed by the NAS report are reporting of results and sampling. In an attempt to create greater uniformity among laboratories regarding the content of reports, the NAS recommended all forensic reports, regardless of disciplines, include the following: identification of the tests conducted; certain results of testing; and, potential sources of error and statistical error.[8]

The NAS report noted that "[s]ampling can be a major issue in the analysis of controlled substances."[9] The report further noted that "SWGDRUG and others have proposed statistical and non-statistical methods for sampling, and a wide variety of methods are used."[10]

---

[8] *Id*.

[9] *Id*.

[10] *Id*.