

Peroxide-Forming Chemicals

# Purpose

Peroxide-forming chemicals include many common solvents and reagents that are known to form organic peroxides on exposure to air and light, e.g. tetrahydrofuran, ethers, isopropanol, dioxanes, styrene, 2-hexanol, etc. The relatively weak oxygen- oxygen bond is the characteristic structure of organic and inorganic peroxides molecules and is the basis for their reactivity and tendency for spontaneous decomposition. A combination of factors, including the rate of peroxidation, the maximum peroxide concentration, volatility of the parent compound, and reactivity of the peroxides formed, determines the actual risk. Peroxides are very sensitive to shock, sparks, elevated temperatures, light, strong oxidizing and reducing agents, and friction, such as a cap being twisted open. Peroxides tend to explode violently and are capable of causing serious injury or death to researchers in the laboratory. It is imperative that all researchers learn to recognize and safely handle peroxidizable chemicals.

Peroxide-forming chemicals are classified in groups depending on their ability to form peroxides (see Appendix B for more information).

### Peroxidation Potentials

* **Chemical structures:**
  + Peroxide-forming chemicals invariably contain an auto oxidizable hydrogen atom that is activated by adjacent structural components
  + Appendix A shows peroxidization moieties in order of decreasing hazard.
  + The risk of hazardous peroxidation generally decreases as the molecular weight of the compound increases. Ten or more carbon atoms at a peroxidizable site are considered low risk.

### Storage conditions:

* + Peroxidation may be accelerated by exposure to heat, light, and oxygen or air. Storing chemicals in open, partially empty or transparent containers and at elevated temperature may promote peroxidation.
  + Exposure of susceptible compounds to oxygen always enhances peroxide formation, whereas the effects of heat, light and contaminants are variable and unpredictable.
  + Ultraviolet light, including sunlight, promotes both autooxidation and depletion of inhibitors.

### Concentration by evaporation or distillation:

* + Distillation, evaporation, or other concentration of some peroxide- forming chemicals can present a high risk of explosion.
    - Distillation of chemical removes stabilizers or inhibitors.
    - Peroxides are less volatile than the parent compound, and thus they concentrate as the parent compound evaporates.
  + Chemicals fall into Group B (see Appendix B) do not usually accumulate potentially explosives concentrations unless the volatile organic material is reduced in volume e.g. evaporation and distillation of diethyl ether, tetrahydrofuran, cyclohexane, glycol ethers and isopropanol.
  + Most of the solvents in Group B are also volatile so that repeated opening of a container may allow enough evaporation and exposure to atmospheric oxygen to concentrate peroxides to a dangerous level.

### Inhibitors:

* + Peroxide-forming chemicals may be inhibited or uninhibited (this will likely be indicated on the chemical container).
  + Inhibition slows but does not eliminate peroxide formation. Inhibitors are depleted as peroxides are formed and degraded. Eventually, the inhibitor is totally depleted, and the peroxide-forming chemical will act as an uninhibited chemical. This may result in the rapid accumulation of peroxides in a chemical that has been stable for a long time.
  + An inhibitor such as hydroquinone, 2,6-di-tert-butyl-p-methylphenol (BHT), diphenylamine, or a similar compound is added to the chemical in trace quantities.
  + Use and storage under an inert atmosphere greatly reduces peroxidation in most cases. Phenolic compounds are often added to commercial vinyl monomers, which are ineffective if some oxygen is not present; thus, these inhibited chemicals should not be stored under inert gas.
  + Diethyl ether should be stored in steel containers because the iron tends to reduce peroxides. However, iron and other metals are not known to be effective for other chemicals.

# Scope

This Standard Operating Procedure (SOP) provides information and procedures to assure that peroxide-forming chemicals are used, stored, and disposed of safely. If the PI determines that a material-specific and experiment-specific SOP for their work with peroxide-formers is warranted, this SOP can be used as a guideline.

# Procedures

## Before Purchase

* + - **Information**: Read this SOP and safety data sheet (SDS) for all peroxide- forming chemicals being used. Due to the severe potential hazards of peroxide-forming chemicals, carefully review the handling and storage procedures and become familiar with the chemical and physical properties of each chemical before beginning work. Always review the incompatibility with other substances and the conditions to which the chemicals are sensitive. Always read the manufacturers’ recommendations contained in supplementary documents, such as technical bulletins.
    - **Identification of Peroxide Groups:** Appendix B lists some peroxide-forming chemicals in the following groups:
      * Group A chemicals can form explosive levels of peroxides without concentration. Some of these chemicals may form explosive concentrations even if never opened.
      * Group B chemicals do not usually accumulate potentially explosives concentrations unless the volatile organic material is reduced in volume e.g. evaporation and distillation.
      * Group C chemicals may autopolymerize as a result of peroxide formation.
      * Group D chemicals may form peroxides, but these chemicals are not well characterized.

Depending on which group that peroxide-forming chemical falls in, it determines the safe storage periods (Appendix C) and testing frequency (Appendix D).

* + - **Engineering Controls:** Peroxide-forming chemicals should be used in a chemical fume hood with the sash as low as feasible.
    - **Training**: Anyone using peroxide-forming chemicals should have adequate training and knowledge of their hazards and of the practices and procedures for working with them safely. See Section 5 for detailed training requirements. Appendix D provides some of the main guidelines for safe handling and disposal of peroxide-forming chemicals.

### Purchasing:

* Determine amount you need and check inventory before ordering. Minimize the amount purchased at one time and purchase just before use. Purchase only an amount that will be used up within the safe storage time periods provided in Appendix C.
* Always purchase with an inhibitor if available unless your specific experiment will not tolerate the inhibitor molecule.
* Purchase peroxide test strips as well.
  + - **Personal Protective Equipment**: Wear gloves, lab coat, and eye protection when using peroxide-forming chemicals.

## Upon Receiving Chemical

* + - **Labeling:** Check for manufacturer’s expiration date & inhibitor info on the container. Label all containers with the date received, the date opened and assign an expiration date if one is not supplied by the manufacturer and update as necessary. Affixing a label stating “Peroxide-Forming Compound” with test dates and results to alert others is recommended. You may obtain peroxide-forming chemicals stickers from the Safety Coordinator.

### Regular check-ins:

* Assign responsible person to periodically check the receipt, opened, and expiration dates.
* Your lab has an up-to-date chemical inventory in RMM, and there is a filter you can run to extract peroxide forming chemicals inventory. You can also indicate expiration dates and the system can highlight expired chemicals.

### Storage:

* The SDS for each material should be read to determine specific storage recommendations or special storage conditions.
* Although the autoxidation reaction is a relatively slow process (months to years), extended storage provides time for accumulation of unstable products. **Recommended safe storage periods** for peroxide forming chemicals are provided in Appendix C.
* Storage of peroxide forming chemicals in open, partially empty or transparent containers greatly increases the risk of peroxide formation. Store away from light and heat**. Protect from light with amber bottles.**
* Protect from heat, light, friction, static discharge, mechanical shock, contact with a catalyst, physical damage or other conditions listed in the SDS that the compound may be sensitive to.
* Store peroxide-forming chemicals in a flammable cabinet and date the bottle upon receipt and when opened.
* Regularly inventory and monitor the container dates and avoid keeping peroxide-forming chemicals longer than the recommended safe storage periods listed in Appendix B.
* If these chemicals need to be stored at cool temperatures, the lab must use laboratory safe (flammable safe) refrigerators.
* Refrigeration of volatile peroxide is a double-edge sword. In some cases, it slows oxidation. However, peroxide accumulation may actually be enhanced by refrigeration, as the rate of peroxide degradation is slowed more than is the rate of peroxide formation. Excess cooling, approaching the freezing point of the chemical may case the precipitation of peroxides from solution, which makes the container very shock sensitive and dangerous.
* Do not return unused peroxide-forming chemicals to their original containers.

### Usage:

* DO NOT OPEN containers of peroxide-forming chemicals that have obvious precipitation or crystals around the lid, visible discoloration, multiple layers, or stratification. If any of the above changes are noted, treat the chemical as explosive and call EHS at (505) 277-2753 immediately.
* Mixing with other chemicals in experiments should be carefully planned and the potential consequences should be evaluated. An SOP for the experiment may be necessary, as noted above. Safety precautions appropriate to what is expected should be taken.
* Do not use metal spatulas to handle peroxides.
* **Gases:** Peroxidizable pressured gases such as butadiene, tetrafluoroethylene, vinyl acetate and vinyl chloride should be relatively resistant to autoxidation in manufacturer’s cylinders. When transferring to another container in labs, an inhibitor should be placed in receiving vessel. The hazard of peroxide may become much greater if these gases are condensed inside the cylinder or secondary vessel.

### Distillation or Evaporation:

* The autoxidation products are less volatile than the parent compound, and therefore become extremely hazardous when evaporation concentrates the unstable autoxidation products to increasingly dangerous levels.
* **Test for peroxides before distilling or evaporating peroxide- forming chemicals.** Do not distill without treating to remove peroxides. Any distillation operation using peroxide formers should leave at least 10% liquid at the bottom of the flask. During distillation, the solution must be stirred with a magnetic stirrer or an inert gas bleed.
* **Uninhibited Group A and B chemicals**: Can be extremely dangerous to distill or significantly concentrate unless known to be free of peroxidation products.
* **Uninhibited Group C chemicals**: Should not be distilled. It is important to add a suitable polymerization inhibitor prior to distilling or concentrating.

### 2-Propanol (Isopropanol / IPA):

* 2-Propanol is a common solvent in labs, yet awareness around its classification as a Group B peroxide-forming chemical is lacking. There have been several reports of explosions occurring during the distillation of 2-propanol that have resulted in injury to researchers.
* Peroxide formation in 2-propanol depends on storage conditions. Here are the summary findings on a study of peroxide formation in 2- propanol that stored in different types bottles in a hood with constant light for 6 months:
  + Colorless glass media bottle - generate peroxides after a few days and had the highest level of peroxides.
  + Semi-opaque white plastic commercial bottle and squirt bottles – significant amounts of peroxides.
  + Amber bottle and media bottle – trace amounts of peroxide.
* Recommend to store 2-propanol in a flammable cabinet when not in use. Store in amber bottle if you need to keep 2-propanol on bench and in hood.
* 2-Propanol is not readily available with inhibitors. Follow the storage and testing frequency for Uninhibited Group B in Appendix D.
  + After safe storage period, it requires more frequent testing (every 3 months and before each use).
  + When it is stored in dark and closed container, test every 12 months.

## Testing

* + - **Before distilling or evaporating:** Test for peroxides before distilling or evaporating peroxide-forming chemicals.
    - **Periodic testing:** Peroxide levels must **never be allowed to exceed 20 parts-per-million (ppm)**. To ensure that the 20-ppm peroxide level is not exceeded, testing for peroxides according to the frequency specified in Appendix D.
    - **Testing procedures:** The easiest way to test for peroxides is to use peroxide test strips that are a semi-quantitative colorimetric method. Read and follow manufacturer’s instructions to use peroxide test strips. See Appendix F for specific testing instructions.
    - **Records:** Records of the testing date and results should be maintained and also recorded on the label. Write down the test date and results on the bottle. You may obtain peroxide-forming chemicals stickers from the Safety Coordinator.

### Actions:

* Less than 20 ppm: You may keep the chemical until its safe storage period and continue testing periodically according to the frequency specified in Appendix D.
  + Uninhibited Group A, C and D chemicals: Must dispose by recommended safe storage periods.
  + Uninhibited Group B and D chemicals: If plan to store after safe storage period, test quarterly and before each use. Dispose immediately when approaching 20 ppm.
  + Inhibited Group B and D chemicals: If plan to store after safe storage period, test every 6 months and before each use. Dispose immediately when approaching 20 ppm.
* Approaching 20 ppm: Dispose immediately. Indicate peroxide levels and request disposal.
* More than 20 ppm: Contact EHS immediately.

### For peroxide-forming chemicals with visible crystallization or solids formed inside or at the cap, do not test! Contact the EHS (505) 277-2753 to evaluate the container.

* Any peroxidizable chemicals or containers with visible discoloration, crystallization, or liquid stratification should be treated as potentially explosive.
* When chemicals are dispensed from screw cap bottles, some of the liquid may remain on the threads and cap. The liquid evaporates, leaving pure peroxides in the threads of the cap. Unscrewing the cap may initiate an explosion.

## Disposal

* + - Avoid mixing peroxide-forming hazardous waste with other hazardous wastes.
    - Immediately rinse empty containers of peroxide-forming chemicals. Do not let residues evaporate.
    - Any chemical waste streams with concentrations of >25% peroxide-forming chemicals must be tested by the lab and levels indicated on the

hazardous waste label.

* + - Peroxide-forming chemical bottles without received, open or manufacturers expiration dates will need to be tested by the lab prior to disposal, again unless there is visible peroxide formation, at which point EHS should be contacted.
    - Chemicals with organic peroxide levels higher than 20 ppm cannot be transported by our waste disposal vendor over public roadways. Therefore, material with greater than 20 ppm must undergo specialized treatment by professionals following strict safety procedures before it can be disposed. If you have a chemical with peroxide levels above 20 ppm, then call EHS to have the material removed and treated.

## General Emergency Procedures

Plan ahead for possible emergencies involving peroxide-forming chemicals.

* + - All personnel who work in areas where there is the potential for an explosion should be trained in how to respond to an explosion emergency.
    - Prior to using peroxide-forming chemicals, consult the SDS for the

appropriate clean-up supplies and ensure that they are readily available. Spill control materials are designed to be inert and un-reactive with the reagent.

* + - Notify people in the area if a spill occurs. For a large spill, turn off sources of ignition and vacate the lab immediately. Dial 911 for emergency assistance.
    - In case of fire or explosion, activate the fire alarm and dial 911 from a safe location.

# Roles & Responsibilities

## The EHS Office is responsible for:

* + - Providing General Chemical Hygiene Training and Hazard Communication Training that includes information on chemical hazards.
    - Maintaining up-to-date guidance pertaining to peroxide-forming chemicals.
    - Reviewing SOP’s of peroxide-forming chemicals.
    - Addressing questions or concerns pertaining to peroxide-forming chemicals.
    - Assisting with inspections of use and storage areas for peroxide-forming chemicals.

## PIs/Supervisors are responsible for:

* + - Evaluating the need for SOPs for peroxide-forming chemicals that are specific to the laboratory.
    - Ensuring that those individuals that they supervise who work with peroxide- forming chemicals receive adequate training (see Section 5 for training requirements.)
    - Ensuring that peroxide-forming chemicals are used and stored safely in the laboratory/work areas that they supervise.
    - Ensuring peroxide-forming chemicals are used and stored in the smallest quantities necessary in the work areas that they supervise.
    - Ensuring appropriate PPE is available for work with peroxide-forming chemicals.

## The Chemical Hygiene Officer is responsible for:

* + - Addressing questions or concerns regarding the use or storage of peroxide- forming chemicals, and consulting with the EHS Office if necessary.
    - Inspecting chemical storage areas, including the storage areas of peroxide- forming chemicals, and notifying the laboratory personnel and the PI/Supervisor of problems found so that they can be corrected or prevented.

## The Safety Coordinator is responsible for:

* + - Assisting the PI/Supervisors with the safe use and storage of peroxide- forming chemicals in the work area. Specific duties may include periodically inspecting use and storage areas and keeping an inventory of peroxide- forming chemicals.

## Individuals Using Peroxide-forming chemicals are responsible for:

* + - Knowing and following the peroxide-forming chemicals SOPs established in their laboratory/work area.
    - Assuring that they have adequate training.
    - Using materials in accordance with training guidance provided, such as SOPs.
    - Reporting any incidents, problems or concerns with handling materials to PI or Safety Coordinator.
    - Wearing the PPE that is specified.
    - Test peroxide-forming chemicals as specified.

# Training

Lab-Specific Training should include the following information:

* The hazards and safe use of peroxide-forming chemicals.
* The location and function of specialized equipment needed for the safe use and storage of peroxide-forming chemicals, including details about lab procedures for storage of the chemicals.
* Procedures in case of an emergency with peroxide-forming chemicals.
* The location of SDSs and SOPs for peroxide-forming chemicals.

Awareness level training should be given to others who work in areas where peroxide-forming chemicals are present.

# Monitoring Requirements

Work areas where peroxide-forming chemicals are used and stored should be inspected at least twice a year to ensure that they are being used and stored safely and in accordance with the rules established for the area. Peroxide-forming chemicals that are no longer needed, past the safe storage period or contain peroxide more than 20 ppm should be identified and action taken to properly dispose of the chemicals. Contact the Safety Coordinator or EHS for assistance as needed.

# Record Management

The Safety Coordinator and EHS shall maintain records of inspections of storage areas containing peroxide-forming chemicals.

# Appendices

# Appendix A: Peroxidizable Organic Moieties

# Appendix B: Peroxide-Forming Chemicals

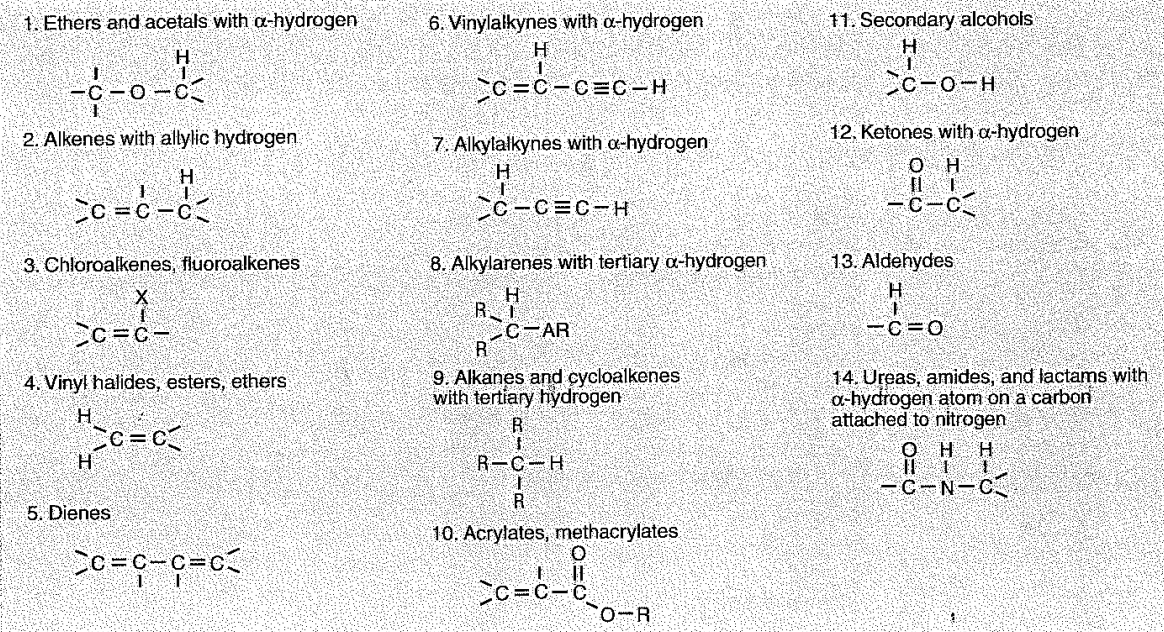
# Appendix C: Safe Storage Periods for Peroxide-Forming Chemicals

# Appendix D: Quick Guide for Peroxide-Forming Chemicals

# Appendix E: Example of Peroxide-Forming Chemicals Label

# Appendix F: Testing Procedure

# Appendix A: Peroxidizable Organic Moieties



**Figure 1: Peroxidizable organic moieties, numbered from most (1) to least (14) likely to form dangerous peroxides.**

Peroxide-forming chemicals invariably contain an auto oxidizable hydrogen atom that is activated by adjacent structural components. Activated hydrogen atoms are often on a:

* + - Methylene group adjacent to an ethereal oxygen atom (-O-CH2-, e.g. diethyl ether, THF, dioxane, diglyme)
    - Methylene group adjacent to a vinyl group or benzene ring (C=C-CH2- or Ph-CH2-, e.g. allyl or benzyl compounds)
    - CH group adjacent to two ethereal oxygen groups (-O-CH-O-, e.g. acetals or methylenedioxy compounds)
    - CH group adjacent to two methylene groups (-CH2-CH-CH2-, e.g. isopropyl compounds and decahydronaphthalenes)
    - CH group between a benzene ring a methylene group (-CH2-CH-Ph-, e.g. cumene and tetrahydronaphthalenes)
    - A vinyl group (-C=CH2-, e.g. vinyl compounds, dienes, styrenes or other monomers)

Not all compounds containing these groups form peroxides, however, the presence of any of these groups in a compound (especially those with low molecular weight) provide a warning that hazardous concentrations of unstable peroxides might be present. Chemical structures that include more than one of these groups are at particular risk of peroxidation.

For example, isopropyl ether (Group A) is particularly dangerous: the presence of two tertiary carbon atoms in the molecule enhance the tendency to oxidize to corresponding hydroperoxide. The hydroperoxide then polymerizes to form a product that precipitates from the ether solution as an explosive crystalline solid.

# Appendix B: Peroxide-Forming Chemicals

The following lists of chemicals **are not exhaustive**. Researchers must consult the SDS and other information sources for the chemicals used in their work areas to determine the potential for peroxide-formation.

**Group A: Chemicals that form explosive levels of peroxides without concentration**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Synonyms** | **State** |
| Butadiene (1) | 106-99-0 | 1,3-Butadiene | l |
| Chloroprene (1) | 126-99-8 | 2-Chloro-1,3- butadiene | l |
| Divinyl acetylene | 821-08-9 | 1,5-Hexadien- 3-yne | l |
| Isopropyl ether | 108-20-3 |  | l |
| Tetrafluoroethylene (1) | 116-14-3 |  | l |
| Vinylidene chloride | 75-35-4 | 1,1- Dichloroethylene | l |

**Group B: Chemicals that form explosive levels of peroxides on concentration**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Synonyms** | **State** |
| Acetal | 105-57-7 |  | l |
| Acetaldehyde | 75-07-0 |  | l |
| Benzyl alcohol | 100-51-6 |  | l |
| 2-Butanol\*\* | 78-92-2 |  | l |
| Cyclohexanol | 108-93-0 |  | l |
| Cyclohexene | 110-83-8 |  | l |
| 2-Cyclohexen-1-ol | 822-67-3 |  | l |
| Cyclopentene | 142-29-0 |  | l |
| Decahydronaphthalene | 91-17-8 | Decalin | l |
| Diacetylene | 460-12-8 |  | g |
| Dicyclopentadiene | 77-73-6 |  | l |
| Diethylene glycol dimethyl ether | 111-96-6 | Diglyme | l |
| Dioxane | 123-91-1 | 1,4-Dioxane | l |
| Ethylene glycol dimethyl ether | 110-71-4 | 1,2-Dimethoxyethane; Glyme | l |
| Ethyl ether | 60-29-7 | Diethyl ether | l |
| 4-Heptanol | 589-55-9 |  | l |
| 2-Hexanol\*\* | 626-93-7 |  | l |
| Isopropyl benzene | 98-82-8 | Cumene | l |
| Methyl acetylene | 74-99-7 | Propyne | g |
| 3-Methyl-1-butanol | 123-51-3 | Isoamyl alcohol | l |
| Methyl cyclopentane | 96-37-7 |  | l |
| Methyl isobutyl ketone | 108-10-1 | Methyl-i-butyl ketone; MIBK; Isobutyl methyl ketone; Isopropylacetone;  4-Methyl-2-pentanone | l |
| 4-Methyl-2-pentanol | 108-11-2 | Isobutyl methyl carbinol; 3-MIC; MAOH; MIBC | l |
| 2-Pentanol\*\* | 6032-29-7 |  | l |
| 4-Penten-1-ol | 821-09-0 |  | l |
| 1-Phenylethanol | 98-85-1 | alpha-Methyl-benzyl alcohol | l |
| 2-Phenylethanol | 60-12-8 | Phenethyl alcohol | l |

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Synonyms** | **State** |
| 2- Propanol\*\* | 67-63-0 | Isopropanol; Isopropyl  alcohol; IPA; sec-Propyl alcohol |  |
| Tetrahydrofuran | 109-99-9 |  | l |
| Tetrahydronaphthalene | 119-64-2 | 1,2,3,4-  Tetrahydronaphthalene; Tetralin solvent | l |
| Vinyl Ethers |  |  |  |
| Other secondary alcohols |  |  |  |

**Group C: Chemicals that may auto-polymerize as a result of peroxide accumulation**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Synonyms** | **State** |
| Acrylic acid (2) | 79-10-7 |  | l |
| Acrylonitrile (2) | 107-13-1 |  | l |
| Butadiene (3) | 106-99-0 |  | g |
| Chloroprene (3) | 126-99-8 | 2-Chloro-1,3-butadiene | g |
| Chlorotrifluoroethylene (3) | 79-38-9 |  | g |
| Methyl methacrylate (2) | 80-62-6 |  | l |
| Styrene | 100-42-5 |  | l |
| Tetrafluoroethylene (3) | 116-14-3 |  | g |
| Vinyl acetate | 108-05-4 |  | l |
| Vinylacetylene | 689-97-4 | Buten-3-yne; Butenyne; 1-Buten-3-yne | g |
| Vinyl chloride (3) | 75-01-4 | Mono-chloroethylene | g |
| Vinylidene chloride | 75-35-4 | 1,1-Dichloroethylene | l |
| 2-Vinyl pyridine | 100-69-6 |  | l |
| 4-Vinyl pyridine | 100-43-6 |  | l |

**Note**: \*\*Secondary alcohols can be peroxide-forming chemical hazards, particularly anhydrous form of the alcohols, and are used in chemical processes (e.g., heating, distilling, performing chemical reactions, performing bulk evaporations). If these chemicals are used only for wipe cleaning or solvent extractions, risk is lower, nonetheless, peroxide may form when exposed to lights and air.

**Group D: Chemicals that may form peroxides but cannot be clearly placed in Groups A-C.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Chemical Name** | **CAS** |
| Acrolein | 107-02-8 | 1,3-Dioxepane | 505-65-7 |
| Allyl ether(4) | 557-40-4 | Di(1-propynl) ether(6) | 111-43-4 |
| Allyl ethyl ether | 557-31-3 | Di(2-propynl) ether |  |
| Allyl phenyl ether | 1746-13-0 | Di-n-propoxymethane(4) | 505-84-0 |
| p-(n-Amyloxy)benzoyl chloride | 36823-84-4 | 1,2-Epoxy-3-isopropoxypropane(4) | 4016-14-2 |
| n-Amyl ether | 693-65-2 | 1,2-Epoxy-3-phenoxypropane | 122-60-1 |
| Benzyl n-butyl ether(4) | 588-67-0 | p-Ethoxyacetophenone | 1676-63-7 |
| Benzyl ether(4) | 103-50-4 | 1-(2-Ethoxyethoxy)ethyl acetate |  |
| Benzyl ethyl ether(4) | 539-30-0 | 2-Ethoxyethyl acetate | 111-15-9 |
| Benzyl methyl ether | 538-86-3 | (2-Ethoxyethyl)-o-benzoyl benzoate | 604-63-7 |
| Benzyl-1-napthyl ether(4) | 613-62-7 | 1-Ethoxynaphthalene | 5328-01-8 |
| 1,2-Bis(2-chloroethoxy)ethane | 112-26-5 | o,p-Ethoxyphenyl isocyanate |  |
| Bis(2-ethoxyethyl)ether | 112-36-7 | 1-Ethoxy-2-propyne |  |
| Bis(2-(methoxyethoxy)ethyl) ether | 143-24-8 | 3-Ethoxypropionitrile | 2141-62-0 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemical Name** | **CAS** | **Chemical Name** | **CAS** |
| Bis(2-chloroethyl) ether | 111-44-4 | 2-Ethylacrylaldehyde oxime | 99705-27-8 |
| Bis(2-ethoxyethyl) adipate | 109-44-4 | 2-Ethylbutanol | 97-95-0 |
| Bis(2-ethoxyethyl) phthalate | 605-54-9 | Ethyl-b-ethoxypropionate | 763-69-9 |
| Bis(2-methoxyethyl) carbonate | 626-84-6 | 2-Ethylhexanal | 123-05-7 |
| Bis(2-methoxyethyl) ether | 119-96-6 | Ethyl vinyl ether | 109-92-2 |
| Bis(2-methoxyethyl) phthalate | 117-82-8 | Furan | 110-00-9 |
| Bis(2-methoxymethyl) adipate |  | 2,5-Hexadiyn-1-ol | 28255-99-4 |
| Bis(2-n-butoxyethyl) phthalate | 117-83-9 | 4,5-Hexadien-2-yn-1-ol | 2749-79-3 |
| Bis(2-phenoxyethyl) ether | 622-87-7 | n-Hexyl ether | 112-58-3 |
| Bis(4-chlorobutyl) ether | 6334-96-9 | o,p-Iodophenetole |  |
| Bis(chloromethyl) ether | 542-88-1 | Isoamyl benzyl ether(4) | 122-73-6 |
| 2-Bromomethyl ethyl ether | 13057-17-5 | Isoamyl ether(4) | 544-01-4 |
| β-Bromophenetole | 589-10-6 | Isobutyl vinyl ether | 109-53-5 |
| o-Bromophenetole | 583-19-7 | Isophorone | 78-59-1 |
| p-Bromophenetole | 588-96-5 | β-Isopropoxypropionitrile(4) | 110-47-4 |
| 3-Bromopropyl phenyl ether | 588-63-6 | Isopropyl-2,4,5-trichlorophenoxy acetate | 93-78-7 |
| 1,3-Butadiyne | 460-12-8 | Limonene | 138-86-3 |
| Buten-3-yne | 689-97-4 | 1,5-p-Methadiene |  |
| Tert-Butyl ethyl ether | 637-92-3 | Methyl p-(n-amyloxy)benzoate |  |
| Tert-Butyl methyl ether | 1634-04-4 | 4-Methyl-2-pentanone | 108-10-1 |
| n-Butyl phenyl ether | 1126-79-0 | n-Methylphenetole |  |
| n-Butyl vinyl ether | 111-34-2 | 2-Methyltetrahydrofuran | 96-47-9 |
| Chloroacetaldehyde diethylacetal(4) | 621-62-5 | 3-Methoxy-1-butyl acetate | 4435-53-4 |
| 2-Chlorobutadiene | 126-99-8 | 2-Methoxyethanol | 109-86-4 |
| 1-(2-Chloroethoxy)-2-phenoxyethane | 2243-44-9 | 3-Methoxyethyl acetate |  |
| Chloroethylene | 75-01-4 | 2-Methoxyethyl vinyl ether | 1663-35-0 |
| Chloromethyl methyl ether(5) | 107-30-2 | Methoxy-1,3,5,7-cyclooctatetraene |  |
| β-Chlorophenetole | 622-86-6 | β-Methoxypropionitrile | 110-67-8 |
| o-Chlorophenetole | 614-72-2 | m-Nitrophenetole | 621-52-3 |
| p-Chlorophenetole | 622-61-7 | 1-Octene | 111-66-0 |
| Cyclooctene(4) | 931-88-4 | Oxybis(2-ethyl acetate) | 628-68-2 |
| Cyclopropyl methyl ether | 540-47-6 | Oxybis(2-ethyl benzoate) |  |
| Diallyl ether(4) | 557-40-4 | β,β-Oxydipropionitrile | 1656-48-0 |
| p-Di-n-butoxybenzene |  | 1-Pentene | 109-67-1 |
| 1,2-Dibenzyloxyethane(4) | 622-22-0 | Phenoxyacetyl chloride | 701-99-5 |
| p-Dibenzyloxyethane(4) |  | α-Phenoxypropionyl chloride | 122-35-0 |
| 1,2-Dichloroethyl ethyl ether | 623-46-1 | Phenyl-o-propyl ether |  |
| 2,4-Dichlorophenetole | 5392-86-9 | p-Phenylphenetone |  |
| Diethoxymethane(4) | 462-95-3 | n-Propyl ether | 111-43-3 |
| 2,2-Diethoxypropane | 126-84-1 | n-Propyl isopropyl ether | 627-08-7 |
| Diethyl ethoxymethylenemalonate | 87-13-8 | Sodium 8,11,14-eicosatetraenoate |  |
| Diethyl fumarate(4) | 623-91-6 | Sodium ethoxyacetylide(6) |  |
| Diethyl acetate(4) | 105-57-7 | Tetrahydropyran | 142-68-7 |
| Diethylketene(6) | 24264-08-2 | Triethylene glycol diacetate | 111-21-7 |
| m,o,p-Diethoxybenzene |  | Triethylene glycol dipropionate | 141-34-4 |
| 1,2-Diethoxyethane | 629-14-1 | 1,3,3-Trimethoxypropane(4) |  |
| Dimethoxymethane(4) | 109-87-5 | 1,1,2,3-Tetrachloro-1,3-butadiene | 921-09-5 |
| 1,1-Dimethoxyethane(4) | 534-15-6 | 4-Vinyl cyclohexene | 100-40-3 |
| Dimethylketene(6) |  | Vinylene carbonate | 872-36-6 |
| 3,3-Dimethoxypropene | 6044-68-4 | Vinylidiene chloride(4) | 75-35-4 |
| 2,4-Dinitrophenetole | 610-54-8 |  |  |

1. When stored as a liquid monomer.
2. Although these form peroxides, no explosions involving these monomers have been reported.
3. When stored in liquid form, these chemicals form explosive levels of peroxides without concentration. They may also be stored as a gas in gas cylinders. When stored as a gas, these

chemicals may auto-polymerize as a result of peroxide accumulation.

1. These chemicals easily form peroxides and should probably be considered under part B.
2. OSHA-regulated carcinogen
3. Extremely reactive and unstable compound.

# Appendix C: Safe Storage Periods for Peroxide Forming Chemicals

|  |  |
| --- | --- |
| **Peroxide forming chemical** | **Safe storage period** |
| Unopened chemicals from manufacturer | Up to 12 months or manufacturer’s expiration date whichever comes first |
| Opened containers: Chemicals in Group A | 3 months or manufacturer’s expiration date whichever comes first |
| Opened containers: Chemicals in Group B and D | 12 months or manufacturer’s expiration date whichever comes first |
| Opened uninhibited chemicals in Group C | 24 hours |
| Opened inhibited chemicals in Group C | 12 months**\*** or manufacturer’s expiration date whichever comes first |

**\***Do not store under inert atmosphere, oxygen required for inhibitor to function.

# Appendix D: Quick Guide for Peroxide-Forming Chemicals

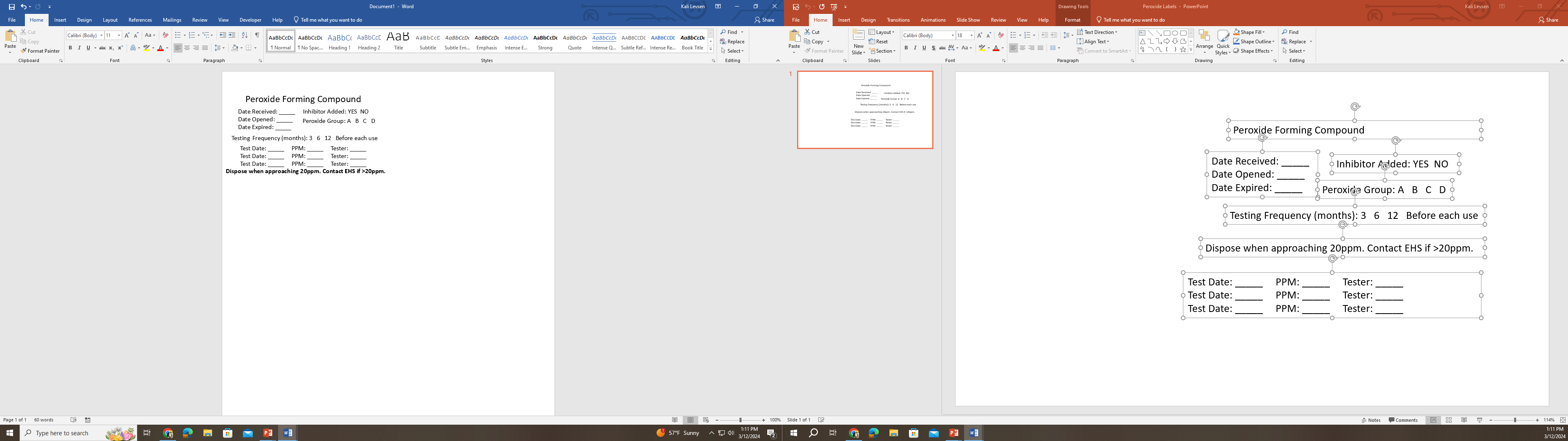
Peroxide-forming chemicals include many common solvents and reagents that are known to form organic peroxides on exposure to air and light, e.g. tetrahydrofuran, ethers, isopropanol, dioxanes, styrene, 2- hexanol, etc. Peroxides are very sensitive to shock, sparks, elevated temperatures, light, strong oxidizing and reducing agents, and friction, such as a cap being twisted open.

This quick guide provides some of the main guidelines for safe handling and disposal of peroxide-forming chemicals:

* 1. Determine the Group of the chemical based on the potential of peroxide formation.
  2. Purchase only what you need and always with an inhibitor if available (unless your specific experiment will not tolerate the inhibitor molecule).
  3. Label with date received, date opened and assign an expiration date if one is not supplied by the manufacturer. Obtain peroxide-forming chemicals stickers from the Safety Coordinator.
  4. Use or dispose of chemical by expiration date.
  5. Protect from light with amber bottles.
  6. Test peroxide periodically as specified in table below. Test before each use for distillation or evaporation. Uninhibited Group C chemicals should not be distilled.
  7. Write down the test date and results on the bottle.
  8. **Do not attempt to test if there are crystals or particles in bottle or around cap.**
  9. **Dispose expired or chemical containing peroxides approaching 20 ppm immediately**.
     + Selected peroxide-forming chemicals may be allowed after safe storage period, subjected to more frequent testing and before each use.
  10. Place waste label on container, indicate peroxide levels, and request disposal.
  11. **If > 20 ppm or observed presence of crystals or particles, contact EHS immediately.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Group** | **A** | **B** | **C** | **D** |
| Peroxide formation | Can form explosive levels of peroxides without concentration. Some of these chemicals may form explosive concentrations even if never opened. | Do not usually accumulate potentially explosives concentrations unless the volatile organic material is reduced in volume e.g. evaporation  and distillation | May auto-polymerize as a result of peroxide formation | May form peroxides but cannot be clearly placed in Groups A-C |
| Examples | 1,3-butadiene; Isopropyl ether; Vinylidene chloride | Tetrahydrofuran; Ethers; Isopropanol; Dioxanes; 2-Hexanol; Acetaldehyde | 1,3-butadiene; Acrylonitrile; Acrylic acid; Vinyl pyridine; Methyl methacrylate;  Styrene; Vinyl acetate | Acrolein; Ethers; Furan; 2-Methoxyethanol; 2- Methyltetrahydrofuran; 1-Octene |
| **Safe Storage Period** | | | | |
| Open & Uninhibited | 3 months | 12 months | 24 hours | 12 months |
| Open & Inhibited | 12 months | 12 months | 12 months | 12 months |
| Unopen | 12 months | 12 months | 12 months | 12 months |
| **Testing Frequency** | | | | |
| Within Safe Storage Period | 3 months | 6 months | 6 months | 6 months |
| After Safe Storage Period | Uninhibited – Must dispose by 3 months  Inhibited – Must dispose by 12 months. | Uninhibited – Test every 3 months and before each use Inhibited – Test 6 months and before each use  \*For isopropanol that is stored in dark and closed container, test  every 12 months. | Uninhibited – Must dispose by 24 hours Inhibited – Test every 6 months and before each use | Uninhibited – Test every 3 months and before each use Inhibited – Test every 6 months and before each use |

**Appendix E: Peroxide-Forming Chemicals Label**



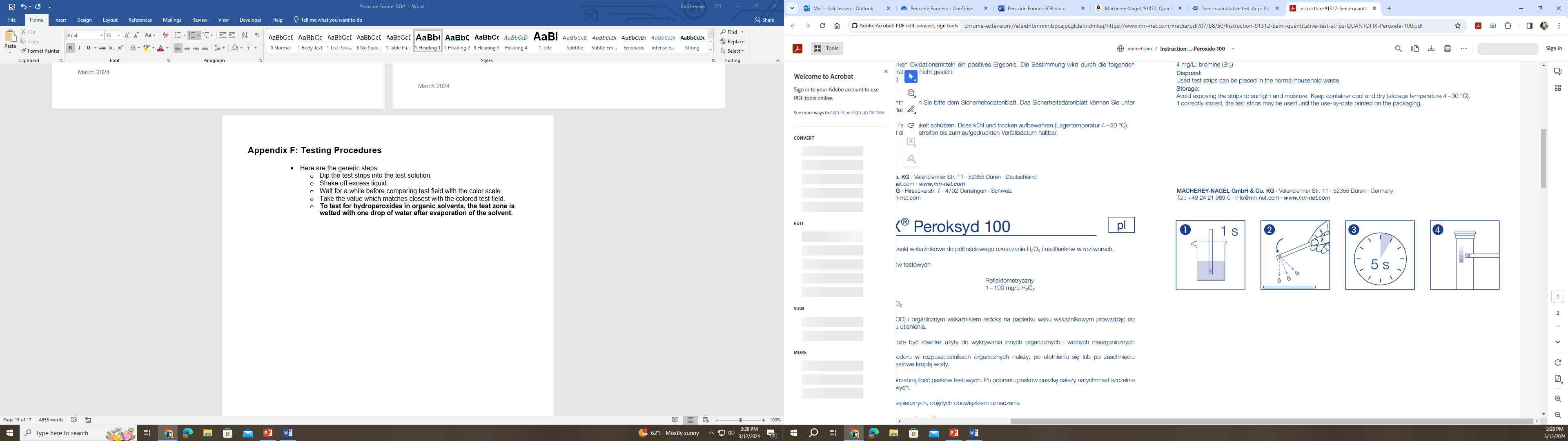
**Appendix F: Testing Procedure**

**QUANTOFIX® Peroxide 100 test strips are used by EHS’s hazardous waste vendor. To be as consistent as possible, we use the same brand of test strips in our department.**

**Instructions for use:** Remove only as many test strips as are required. Close the container immediately after removing a strip. Do not touch the test fields.

1. Dip the test strip into the test solution for 1 second.
2. Shake off excess liquid.
3. Wait 5 seconds. (When detecting hydroperoxides in organic solvents, moisten the test field with 1 drop of water after evaporation / drying of the solvent.)
4. Compare test field with the color scale. If hydrogen peroxide is present, the test field turns blue. Take the value which matches closest with the colored test field.

**\*Color changes after 1 minute do not represent a positive reaction.**



**Interferences:** If the sample solution has a pH value of 2 – 9, the reaction will take place without interferences. Strong acid solutions must be buffered with sodium acetate, and alkaline solutions with citric acid to a pH of 5 – 7. The presence of other strong oxidants will also lead to false positive results. The following ions interfere with the determination only when the concentrations below are exceeded: 3 mg/L: free chlorine (hypochlorite) 4 mg/L: bromine (Br₂)

**Disposal:** Used test strips can be placed in the normal household waste.