Crosslinking peroxides for elastomers and thermoplastics

Perkadox® and Trigonox®
Nouryon’s range of organic peroxides for the crosslinking of elastomers and thermoplastics is the world’s largest. Companies all over the world depend on our Trigonox® and Perkadox® organic peroxide brands. Why? Because they are an important ingredient in the production of everything from hi-tech automotive parts such as hoses and belts to shoe soles and power distribution cables.

Examples include:
- **Trigonox 311**
  PEX pipes, rotomolding
- **Trigonox 145**
  PEX pipes, rotomolding
- **Trigonox 101**
  PEX pipes, polymer modification, technical rubber goods
- **Trigonox T**
  wire & cable (direct peroxide injection)
- **Perkadox 14**
  wire & cable, technical rubber goods footwear
- **Perkadox BC**
  wire & cable, footwear, technical rubber goods
- **Trigonox 117**
  for EVA-film (encapsulant)
- **Trigonox 29**
  for fast on-set of cure
- **Perkadox PD-50S-ps**
  extruded silicone rubber articles such as auto ignition cable, seals & tubes

Much of our success is due to our philosophy of creating close partnerships with our customers. What do you want to achieve? From optimizing applications, improving efficiencies, resolving difficulties or even developing new crosslinking peroxides, we’re happy to meet with you to discuss your requirements.

This product guide provides an overview of our main, commercially available crosslinking peroxides. We invite you to visit us at https://polymerchemistry.nouryon.com for complete product listings.

Formulations with phlegmatizers and carriers or concentrations other than those indicated, as well as unique custom made peroxide compositions can be made available with due observance of safety characteristics and the appropriate environmental and transportation regulations. Whatever your particular requirements, we can develop the product to match.
<table>
<thead>
<tr>
<th>Product name</th>
<th>Chemical name [CAS no.]</th>
<th>Mol. weight (g/mol)</th>
<th>Assay (%)</th>
<th>Main carrier / solvent</th>
<th>Safe processing temperature (°C)</th>
<th>Typical crosslink temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,3,5,7,7-Pentamethyl-1,2,4-trioxepane [215877-64-8]</td>
<td>174.3</td>
<td>95</td>
<td></td>
<td></td>
<td>180</td>
<td>220</td>
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<tr>
<td>2,5-Dimethyl-2,5-di(tert-butylperoxy)hexyne-3 [1068-27-5]</td>
<td>286.4</td>
<td>85</td>
<td>mineral oil</td>
<td>145</td>
<td>185</td>
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<tr>
<td>2,5-Dimethyl-2,5-di(tert-butylperoxy)hexane [78-63-7]</td>
<td>290.4</td>
<td>92</td>
<td>silica</td>
<td>135</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>tert-Butyl cumyl peroxide [3457-61-2]</td>
<td>208.3</td>
<td>95</td>
<td></td>
<td></td>
<td>135</td>
<td>175</td>
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<tr>
<td>tert-butylperoxyisopropylbenzene [25155-25-3; 2212-81-9]</td>
<td>338.5</td>
<td>98</td>
<td>calcium carbonate</td>
<td>135</td>
<td>175</td>
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<tr>
<td>Dicumyl peroxide [80-43-3]</td>
<td>270.4</td>
<td>99</td>
<td>calcium carbonate</td>
<td>130</td>
<td>170</td>
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</tr>
</tbody>
</table>

1 Trigonox B has a boiling point of 110°C and a flash point of 6°C. Therefore, it is not recommended for standard rubber mixing procedures carried out in closed mixers (kneading mixer type) or on an open two-roll mill.

2 Other concentrations are available on request.
<table>
<thead>
<tr>
<th>Product name</th>
<th>Chemical name [CAS no.]</th>
<th>Mol. weight</th>
<th>Assay (%)</th>
<th>Main carrier / solvent</th>
<th>Safe processing temperature (°C)</th>
<th>Typical crosslink temperature (°C)</th>
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<tbody>
<tr>
<td>Butyl 4,4-di(tert-butylperoxy)valerate [995-33-5]</td>
<td>334.5</td>
<td>40</td>
<td>calcium carbonate</td>
<td>125</td>
<td>160</td>
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<tr>
<td>Trigonox 17-408-PD/GR</td>
<td></td>
<td></td>
<td>calcium carbonate</td>
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<tr>
<td>Trigonox 17-40MB-GR</td>
<td></td>
<td></td>
<td>calcium carbonate</td>
<td></td>
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<tr>
<td>tert-Butylperoxy 2-ethylhexyl carbonate [34443-12-4]</td>
<td>246.3</td>
<td>&gt;98</td>
<td></td>
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<td></td>
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<tr>
<td>Trigonox 117</td>
<td></td>
<td></td>
<td>EPR, calcium carbonate</td>
<td></td>
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<tr>
<td>1,1-Di(tert-butylperoxy)-3,3,5-trimethylcyclohexane [6731-36-8]</td>
<td>302.5</td>
<td>40</td>
<td>calcium carbonate</td>
<td>115</td>
<td>145</td>
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<tr>
<td>Trigonox 29-408-PD/GR</td>
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<td>calcium carbonate</td>
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<tr>
<td>Trigonox 29-40MB-GR</td>
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<td></td>
<td>calcium carbonate</td>
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<tr>
<td>tert-Butyl peroxybenzoate [614-45-9]</td>
<td>194.2</td>
<td>98</td>
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<tr>
<td>Trigonox C</td>
<td></td>
<td></td>
<td>silica</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Di(4-methylbenzoyl) peroxide [895-85-2]</td>
<td>270.3</td>
<td>50</td>
<td>silicone oil</td>
<td>85</td>
<td>110</td>
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<tr>
<td>Perkadox PM-50S-PS</td>
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<tr>
<td>Dibenzoyl peroxide [94-36-0]</td>
<td>242.2</td>
<td>50</td>
<td>silicone oil</td>
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<td>105</td>
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<td>Perkadox L-50S-PS</td>
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<tr>
<td>Di(2,4-dichlorobenzoyl) peroxide [133-14-2]</td>
<td>380.0</td>
<td>50</td>
<td>silicone oil</td>
<td>75</td>
<td>90</td>
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<tr>
<td>Perkadox PD-50S-PS</td>
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</tr>
</tbody>
</table>

PD = powder
GR = granules
PS = paste
MB = EPR bound
Recommended dosage levels

<table>
<thead>
<tr>
<th>Peroxide</th>
<th>Trigonox 29-40</th>
<th>Trigonox 17-40</th>
<th>Perkadox BC-40</th>
<th>Perkadox 14-40</th>
<th>Trigonox 101-45</th>
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<tbody>
<tr>
<td>Safe Processing Temperature (°C)</td>
<td>115</td>
<td>125</td>
<td>130</td>
<td>135</td>
<td>135</td>
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<tr>
<td>Typical Crosslink Temperature (°C)</td>
<td>145</td>
<td>160</td>
<td>170</td>
<td>175</td>
<td>175</td>
</tr>
<tr>
<td>NR; IR</td>
<td>2.3 - 4.5</td>
<td>2.5 - 5.0</td>
<td>2.0 - 4.1</td>
<td>1.3 - 2.5</td>
<td>1.3 - 2.4</td>
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<tr>
<td>BR</td>
<td>1.0 - 2.1</td>
<td>1.1 - 2.3</td>
<td>0.9 - 1.9</td>
<td>0.5 - 1.2</td>
<td>0.5 - 1.2</td>
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<tr>
<td>CR</td>
<td>1.1 - 3.0</td>
<td>1.3 - 3.3</td>
<td>1.0 - 2.7</td>
<td>0.6 - 1.7</td>
<td>0.6 - 1.6</td>
</tr>
<tr>
<td>SBR</td>
<td>1.9 - 4.1</td>
<td>2.1 - 4.6</td>
<td>1.7 - 3.7</td>
<td>1.1 - 2.3</td>
<td>1.1 - 2.2</td>
</tr>
<tr>
<td>NBR</td>
<td>2.6 - 4.5</td>
<td>2.9 - 5.0</td>
<td>2.4 - 4.1</td>
<td>1.5 - 2.5</td>
<td>1.4 - 2.4</td>
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<tr>
<td>HNBR</td>
<td>6.8 - 11.3</td>
<td>7.5 - 12.5</td>
<td>6.1 - 10.1</td>
<td>3.8 - 6.3</td>
<td>3.7 - 6.1</td>
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<tr>
<td>AU (ester type)</td>
<td>5.3 - 9.1</td>
<td>5.8 - 10.0</td>
<td>4.7 - 8.1</td>
<td>3.0 - 5.1</td>
<td>2.9 - 4.9</td>
</tr>
<tr>
<td>EPM, EPDM</td>
<td>6.8 - 11.3</td>
<td>7.5 - 12.5</td>
<td>6.1 - 10.1</td>
<td>3.8 - 6.3</td>
<td>3.7 - 6.1</td>
</tr>
<tr>
<td>PE</td>
<td>1.5 - 7.6</td>
<td>1.7 - 8.4</td>
<td>1.4 - 6.8</td>
<td>0.8 - 4.2</td>
<td>0.8 - 4.0</td>
</tr>
<tr>
<td>CM ¹</td>
<td>6.8 - 10.6</td>
<td>7.5 - 11.7</td>
<td>6.1 - 9.5</td>
<td>3.8 - 5.9</td>
<td>3.7 - 5.7</td>
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<tr>
<td>EVA</td>
<td>2.6 - 5.3</td>
<td>2.9 - 5.8</td>
<td>2.4 - 4.7</td>
<td>1.5 - 3.0</td>
<td>1.4 - 2.9</td>
</tr>
<tr>
<td>Q ²</td>
<td>1.0 - 2.0</td>
<td>0.4 - 0.8</td>
<td>0.4 - 0.8</td>
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<td></td>
</tr>
</tbody>
</table>

¹ Addition of a coagent is recommended.
² Silicone rubber can also be crosslinked with Perkadox PD-50S, Perkadox L-50S and Perkadox PM-50S.

Required amounts of peroxide: 1.1 - 2.3 phr, 0.7 - 1.4 phr and 1.1 - 2.3 phr respectively.
Typical crosslink temperatures 90°C, 105°C and 110°C.

Peroxide versus sulfur crosslinking

**Advantages of peroxide crosslinking in comparison to sulfur cure:**
- Simple formulation.
- Storage of the peroxide-containing compound without bin scorch.
- High processing temperature.
- Rapid vulcanization without reversion.
- Good compression set, particularly at elevated temperatures.
- High temperature resistance.
- Limited extractable constituents from final product.
- No staining of the finished parts.
- No discoloration of crosslinked product by contact with metals and PVC.
- Most peroxides do not cause blooming.
- Co-vulcanization of saturated and unsaturated elastomers.
- Co-vulcanization of elastomers and thermoplastics.
- Copolymerization with polymerizable plasticizers or coagents to give controlled hardness and stiffness, coupled with easy processing.

**Points of attention for peroxide crosslinking:**
- Sensitivity to oxygen under curing conditions.
- Certain components of the rubber compound such as filters, extender oils, antioxidants, resins must be selected with care because they may, under certain conditions, consume free radicals.
- Usually, tensile and tear strength properties are reduced by about 15%, when compared to a conventional sulfur based crosslinking system.
- Scorch and cure time are less flexible, since they are determined mainly by the temperature.
- During cure, some peroxides may lead to distinct odors.
- Post cure may be necessary.
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For product inquiry and ordering information, please contact your Nouryon account manager or regional Nouryon sales office.

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**Additional information**
Product Data Sheets (PDS) and Material Safety Data Sheets (MSDS) for our polymerization initiators are available at polymerchemistry.nouryon.com

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