Intermediates

# 2,6-Naphthalene dicarboxylic acid (HNDA)

BASF
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**BASF is the world's leading chemical company: The Chemical Company. Its portfolio ranges from chemicals, plastics, performance products and crop protection products to oil and gas. We combine economic success with environmental protection and social responsibility. Through science and innovation, we enable our customers in nearly every industry to meet the current and future needs of society. Our products and solutions contribute to conserving resources, ensuring nutrition and improving quality of life. We have summed up this contribution in our corporate purpose: We create chemistry for a sustainable future.**

## Top intermediates supplier

The BASF Group's Intermediates division develops, produces and markets a comprehensive portfolio of some 700 intermediates around the world. The most important of the division's product groups include amines, diols, polyalcohols, acids and specialties. Among other applications, intermediates are used as starting materials for coatings, plastics, pharmaceuticals, textile fibers, detergents and crop protectants. Innovative intermediates from BASF help to improve the properties of final products and the efficiency of production processes. The ISO 9001-certified Intermediates division operates plants at production sites in Europe, Asia-, and the Americas.



# HNDA – specialty monomer for superior polymer resins

*HNDA from BASF is produced as a high purity, white free-flowing powder.*

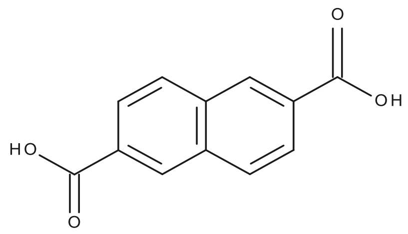
BASF's high-purity 2,6-naphthalene dicarboxylic acid (HNDA) is a key monomer for the production of high-performance polyester, polyamide and liquid crystal polymers. Naphthalate-based polymers made from HNDA are known for their dimensional stability and strength at high temperatures as well as excellent vapor barrier properties. These enhanced polymer properties have led to the growth of HNDA use in applications including electronics, food and beverage packaging and films.

## Unique product

HNDA is a unique naphthalene-based dicarboxylic acid, which is produced by BASF as a white free-flowing powder. BASF's HNDA is manufactured through a unique process to hydrolyze dimethyl-2,6-naphthalene dicarboxylate (NDC), resulting in the high-purity product. The double ring structure of HNDA contributes to the higher performance of resulting polymers. Unlike NDC, polymerization of HNDA occurs through a methanol-free process, removing the need for additional process and safety controls.

## Reliable partner

BASF is the global leader in production of HNDA with more than 15 years of experience. HNDA is available from BASF with the highest product purity and excellent product quality ensured by our unique process technology. BASF supplies HNDA through a global distribution network and regional sales contacts.




*Chemical formula of HNDA*

# HNDA in liquid crystal polymers

*Liquid crystal polymers based on HNDA offer high thermal stability and a natural fire retardant rating for automotive parts.*

HNDA from BASF is a key co-monomer for the production of liquid crystal polymers (LCPs) for high-temperature and high-performance applications. In line with the trend towards miniaturization of electronics, LCPs based on HNDA offer higher thermal stability, a natural fire retardant rating, and improved processing for the fabrication of smaller and more complex parts. Applications for LCPs include electronics, automotive and medical devices.

HNDA can be combined with co-monomers, including 4-hydroxybenzoic acid, hydroquinone, and 4,4'-biphenol, to make Type I or II LCPs, which offer the highest melting points and thermal performance. As demand increases for LCPs with greater heat resistance and flowability, naphthenic LCPs will continue to replace lower performance polymers. BASF provides HNDA with the highest possible purity to meet the needs of LCP formulations.

## Properties of example HNDA-based LCP with 30% glass filler

| | |
|---|---|
| Tensile strength [MPa] | 150.3 |
| Flexural strength [MPa] | 169.6 |
| Flexural modulus [MPa] | 11,729 |
| Elongation at break [%] | 2.7 |
| Notched Izod impact [J/m] | 122.8 |
| Compressive strength [MPa] | 104.8 |
| Melting point [C] | 335 |
| Glass transition temperature [C] | 121 |
| HDT at 1.4 MPa [C] | 256 |
| UL 94 flammability rating | V-0 |
| Specific gravity [g/mL] | 1.67 |

### Improved dimensional stability and high-temperature strength in LCPs

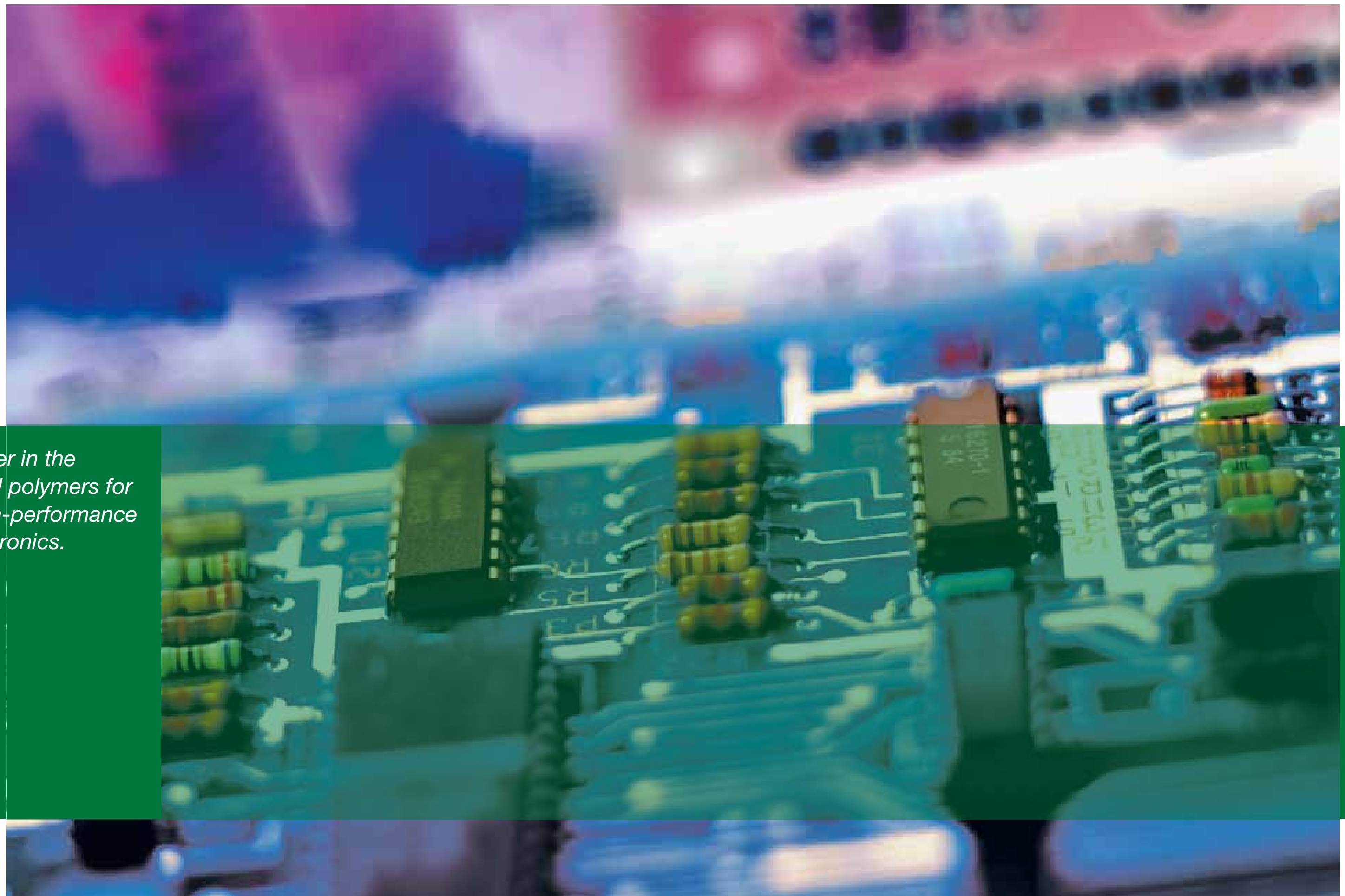
LCPs made from HNDA are known for their dimensional stability and strength at elevated temperatures. These enhanced properties allow for production of thinner connectors and walls for printed circuit boards and microelectronics.

### Natural fire retardant rating

HNDA gives LCPs a natural V-0 flammability rating without the addition of halogens or other undesirable additives.

### Reduced melt flow for faster processing and fabrication of smaller parts

HNDA-based LCPs have outstanding melt-phase viscosity, giving good flowability and reduced processing times. These properties allow for easy injection molding into thin-wall parts that crystallize quickly in the mold cavity. Naphthenic LCPs can be microinjected to manufacture ever smaller components.



*HNDA is a key co-monomer in the production of liquid crystal polymers for high-temperature and high-performance applications, such as electronics.*

# HNDA for high-performance polyester resins

HNDA can polymerize with polyalcohols to give different types of polyesters, including polyethylene naphthalate (PEN) and polybutylene naphthalate (PBN), which incorporate the naphthalate structure of HNDA. For example, HNDA polymerizes with ethylene glycol to form PEN, similar to the preparation of polyethylene terephthalate (PET) from terephthalic acid and ethylene glycol. Naphthalate-based polyesters have significantly improved thermal, mechanical and vapor barrier properties over their terephthalate counterparts and can be used as copolymers or blends with other polyesters to provide improved performance. These superior polymer properties have led to the use of HNDA-containing polyesters in applications including food and beverage packaging, high-performance films, heat sterilizable medical devices and high-temperature cookware.

## Polyesters based on HNDA

| Diacid | Polyalcohol | Polyester |
|---|---|---|
| HNDA | Ethylene glycol | Polyethylene naphthalate (PEN) |
| HNDA | 1,4-Butanediol | Polybutylene naphthalate (PBN) |
| HNDA | 1,3-Propanediol | Polytrimethylene naphthalate (PTN) |

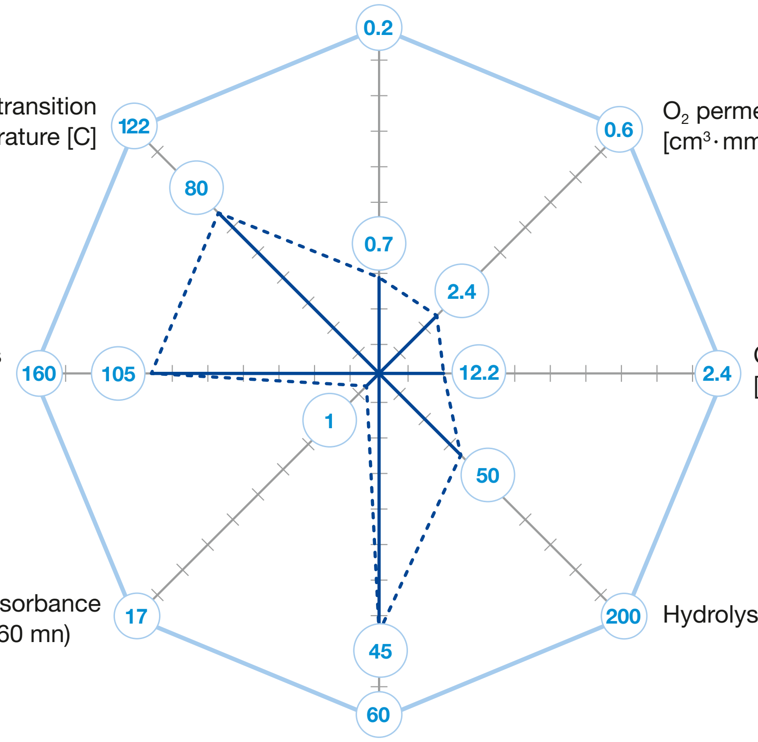
### Enhanced properties in PEN resins

HNDA-based PEN resins show many significant improvements over PET in mechanical, thermal, and barrier properties, as well as better chemical resistance and UV absorbance. Similar trends also exist with other naphthalate-based polyesters. Moderate enhancements can be achieved through copolymerization of HNDA in PET processes.

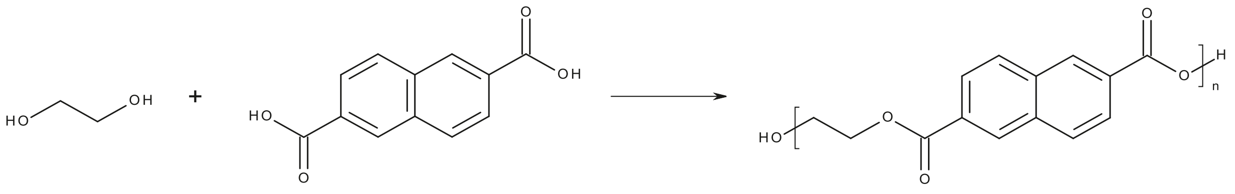
*HNDA-containing polyesters have superior thermal, mechanical, and vapor barrier properties that make them ideal for use in the high-performance films of solar panels.*

## Comparative properties of PET and PEN resins

**With superior attribute values on the outer edge of the figure**




### Polymerization of HNDA with EG to form PEN resin



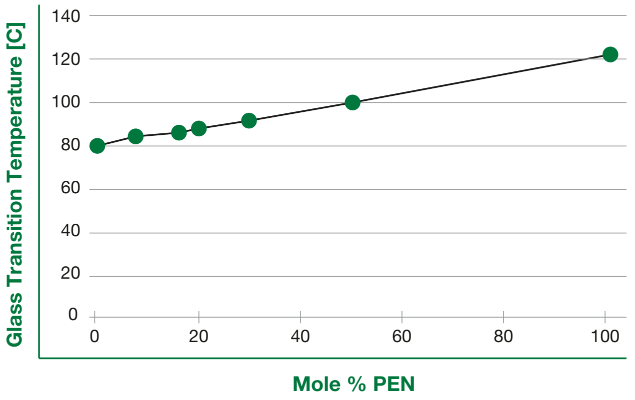
### HNDA in polyester copolymers and blends

For many applications, the full performance benefits of PEN resins may not be required. In these cases, PEN can be combined with established terephthalic acid-based polymers such as PET as a copolymer or blend to enhance the polymer properties. One method to incorporate naphthalene into terephthalic acid-based PET manufacturing processes is copolymerization through replacement of some terephthalic acid with HNDA. In such facilities, HNDA can be used as a direct substitute for terephthalic acid without modification of the polymerization equipment or process.

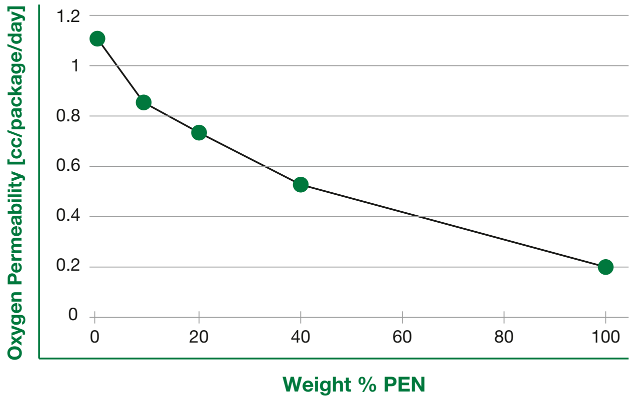
### Properties of naphthalate copolymers

The properties of PET/PEN copolymers and blends will vary based on the HNDA content. For example, both glass transition temperature and vapor barrier properties are directly proportional to the PET/PEN ratio. In addition, copolymers with HNDA can achieve crystallinity at ratios of up to 15% or over 85% naphthalate content while producing a polyester with significant physical property advantages over PET. Therefore, the properties of copolymer and blend formulations can be cost effectively tuned to meet the needs of any application through the addition of HNDA.

## Glass transition temperature as a function of copolymer or blend composition




## Oxygen permeability directly correlates to PET/PEN composition




### Methanol-free polyester manufacturing from HNDA

Similar to terephthalic acid, the use of HNDA does not result in the production of methanol, thereby eliminating the need for supplemental control systems and methanol recovery equipment. Polymerization of HNDA with diols releases water during the condensation, rather than methanol as in the transesterification reaction of dimethyl-2,6-naphthalene dicarboxylate (NDC). HNDA, therefore, is a drop-in solution for the production of PET/PEN copolymers in existing PET plants where terephthalic acid is used as a feedstock.

*Cookware produced with HNDA-based polyesters have a high thermal stability.*



# HNDA in polyester food packaging

HNDA-based polyester resins can be used in a variety of rigid or flexible packaging applications to give increased thermal stability, higher strength, and improved vapor barrier properties. By varying the naphthalate content in the polyester, the final product can be optimized for cost versus required performance properties. The addition of HNDA to PET packaging extends the potential applications of polyester to include hot-fill and heat-sterilized bottles, plastic beer bottles, and packaging for sensitive food products. Furthermore, PEN homopolymers and PET/PEN copolymers and blends containing HNDA at levels from zero to 100 percent are FDA-approved in the United States for food-contact applications.

### HNDA improves thermal stability of polyesters

Perhaps the greatest benefit of polyester packaging using HNDA is its enhanced thermal stability. This heat stability offers many advantages for applications including heat-sterilized baby bottles, pasteurized or hot-filled food and beverage packaging, and microwavable containers. Depending on the customer needs, the ratio of PET and PEN can be varied to optimize cost versus thermal and barrier properties.

### Excellent vapor barrier properties for PEN bottles and films

Polyesters with high naphthalate content also have much better vapor and moisture barrier performance than PET resins. Pure PEN films are over 75% less permeable to oxygen, carbon dioxide and water than those made from pure PET. The gas barrier property advantages of HNDA-based resins allow for their use in demanding applications such as plastic beer bottles and performance food packaging films.

### UV absorbing properties of HNDA-containing polyesters

In addition to boosting the mechanical, thermal, and barrier properties of polyesters, the use of HNDA also provides a barrier to ultraviolet (UV) radiation. Furthermore, PEN resins remain transparent to visible light, resulting in polyester containers that can protect contents from harmful UV rays while maintaining visible transparency. PET and other visibly transparent materials do not successfully block UV radiation. Even at levels of less than 1 weight percent, HNDA-based polyesters offer a very cost-effective solution to UV protection in food and beverage packaging applications. These UV-blocking properties help to maintain product stability, extend shelf life, and protect against product color loss.

*Plastic bottles and food packaging increasingly require the high thermal stability, mechanical strength, and vapor barrier properties enabled by HNDA-based polyester resins.*

# HNDA in specialty polyamide applications

BASF's HNDA can be used to make specialty polyamide resins, either as part of a homopolymer system or as a partial replacement for another dicarboxylic acid in nylon-type systems. Polyamides containing HNDA offer improved thermal and hydrolytic stability as well as better chemical resistance and vapor barrier properties. Applications for naphthalate-based polyamides include automotive parts and other engineering plastics.

### High-performance polyamide homopolymers based on HNDA

HNDA is used, in combination with various diamines, to produce polyamides with excellent heat resistance and mechanical properties. Utilizing the high chemical resistance of HNDA-based polyamides, these polymers have found significant usage in the automotive industry for fuel hoses and other engineering plastics.

### Naphthalate-modified polyamide copolymers

HNDA can replace adipic acid in nylon-type polyamide compositions to improve the polymer thermal and hydrolytic stability while decreasing the required processing temperature. Similar improvements in polymer properties can also be seen in other HNDA-modified polyamide systems. Since naphthalate-based polyamides also see improved UV blocking ability, they find numerous applications in outdoor uses, where high weatherability is important.


*HNDA-based polyamides have high chemical resistance, making them suitable for automotive applications such as fuel hoses.*



# HNDA properties and handling recommendations

*BASF offers HNDA in supersacks as well as 100 kilogram and 25 kilogram fiber drums.*

## Product Properties

| | |
|---|---|
| CAS number | 1141-38-4 |
| Synonyms | 2,6-Naphthalic acid<br>2,6-NDA |
| Empirical formula | $C_{12}H_8O_4$ |
| Molecular weight [g/mol] | 216.3 |
| Organic purity [%, min] | 99.8 |
| Melting point [C] | 300 (>572F) |
| Specific gravity of bulk powder [g/mL] | 0.64 |
| Iron content [ppm] | Max. 5 |
| Nickel content [ppm] | Max. 2 |
| Appearance – visual | White powder |
| Flowability – visual | Free flow |
| Solubility in water at 25C | Nil |

### General handling recommendations

HNDA is not classified as a hazardous substance according to GHS or OSHA and does not contain substances with occupational exposure limit values. In general, HNDA can be handled safely following conventional best available practices for non-toxic solid chemicals in powder form that prevent contact with personnel. Standard precautions such as minimal exposure to moisture or oxygen apply for both quality and safety reasons. As with most combustible solids, measures should be taken to avoid static charge buildup, to minimize dust concentration and to control oxygen levels. As HNDA may cause skin and eye irritation, protective gloves and clothing as well as eye protection should always be worn. For further safety data, please refer to the material safety data sheets.

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