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(54) Title: FLAME RETARDANTS, PROCESSES FOR THEIR PREPARATION AND USES THEREOF IN POLYURETHANE AND POLYISOCYANURATE FOAMS

(57) Abstract: The invention provides pentabromobenzyl moiety containing hydroxy-functional compounds which are useful as flame-retardants in flexible and rigid polyurethane foams and also in rigid polyisocyanurate foams. Processes for preparing the compounds, polyurethane and polyisocyanurate foams containing the compounds are also provided by the invention.

Flame retardants, processes for their preparation and uses thereof in polyurethane and polyisocyanurate foams

Field of the Invention

The present invention provides novel pentabromobenzyl moiety containing hydroxy-functional compounds serving, either with or without the addition of known commercial flame retardants, as highly efficient reactive flame retardants in urethane systems, particularly in flexible and rigid polyurethane foams or rigid polyisocyanurate (PIR) foams.

Background of the Invention

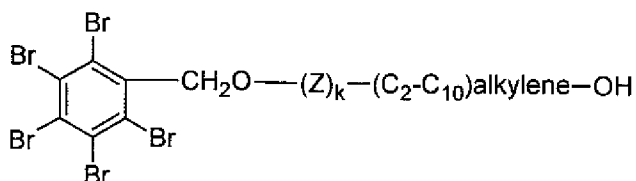
Brominated flame-retardants are known to be highly effective and in many cases are the only option for reducing the fire risk of synthetic materials such as rigid or flexible polyurethane foams. However, the growing concern regarding health and ecological issues has led inventors to develop a new reactive macro-molecular flame retardant.

Environmental and health problems diminish if a flame retardant is either reacted into the polymer matrix and cannot be leached-out, or if the flame retardant has a sufficiently high molecular weight that it does not volatilize, and is not likely to bio-accumulate in living tissues.

Compounds containing a pentabromobenzyl moiety are known as flame retardants. Pentabromobenzyl acrylate (EP 481126), pentabromobenzyl terephthalate (DE 33 20 333), and pentabromobenzyl tetrabromophthalate (EP 47866) are reported to be used in flame retardant polymer compositions.

Low molecular weight pentabromobenzyl alkyl ethers containing one hydroxide group are described in US 2005/0124746. According to said publication, pentabromobenzyl alkyl ethers are prepared by the reaction of a pentabromobenzyl halide (PBBBr) with an aliphatic mono or di-alcohol (or the corresponding metal alcoholate), in the presence or absence of a base. Aliphatic diols (or the corresponding metal alcoholate) are reacted with a pentabromobenzyl halide, preferably PBBBr, to obtain the pentabromobenzyl ethers with one functional -OH group (Formula A).

Formula A:



Z = linear or branched - [(C₂-C₈)alkylene - O]_n

n represents an integer from 2 to 4

k may be 0 or 1;

Summary of the Invention

The present invention provides novel reactive pentabromobenzyl moiety containing hydroxy-functional compounds possessing highly satisfactory flame retarding characteristics and having good compatibility with the polyol components of the polyurethane system. The invention further provides polyurethane and polyisocyanurate compositions comprising said novel pentabromobenzyl moiety containing hydroxy-functional compounds that exhibit excellent fire retardancy.

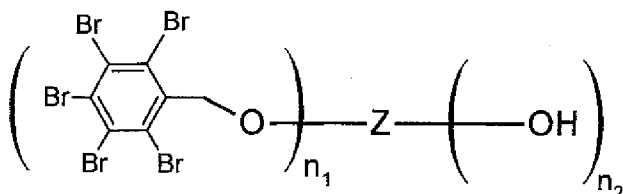
The flame-retardant of the present invention possesses two useful properties, in addition to its high efficacy as a flame retardant: it is both fully reactive through its hydroxyl-functional groups, and is a macro-molecular polymer of up to 3000. This means that the flame retardant of the invention becomes integrated into the polymer substrate, such as a rigid or flexible foam, so that it is not released to the environment and the large molecules are not likely to penetrate through cell membranes of living tissue, and therefore does not pose a health hazard.

The present invention concerns the class of flame retardants obtainable by reacting pentabromobenzyl bromide (chemically named 1,2,3,4,5-pentabromo-6-(bromomethylbenzene) with polymeric polyols having a number of hydroxyl groups that is not less than 3 (with a preferred molecular weight from ~250 to 3000, more preferably from ~250 to 1000, or a mixture of such polyols (see Scheme 1 below)). The polyol utilized as a starting material in the present invention is a branched polyol

having n branches (n is an integer equal to or greater than 3) with n hydroxyl groups, e.g., terminal hydroxyl groups according to the formula $Z(\text{OH})_n$, wherein Z is the branched moiety, which is preferably a branched hydrocarbon including ether linkages, with the molecular weight of Z being between 150 and 3000 Da.

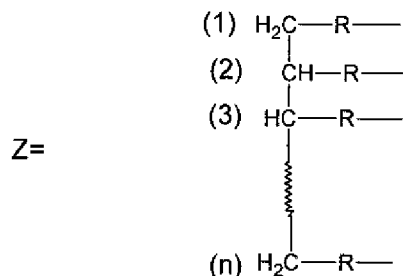
It is noted that the branched polyol contains n hydroxyl groups available for the reaction with pentabromobenzyl bromide. However, the molar ratio between the polyol and the pentabromobenzyl bromide is adjusted such that in the product which is formed some branches are terminated with the pentabromobenzyl group and other branches with the original hydroxyl groups. In this way, a polymeric flame retardant is obtained which carry significant amounts of bromine and is still reactive in polyurethane systems due to the presence of hydroxyl groups. The compounds of the invention are characterized by bromine content between 10 and 65 wt% and hydroxyl value in the range from 20 mg KOH/g to 120 mg KOH/g.

Thus, in one aspect, the invention provides compounds which are pentabromobenzyl alkyl ether containing hydroxyl functionality of Formula 1:



Formula 1

wherein each of n_1 and n_2 is an integer equal to or greater than 1, with their the sum being equal to or greater than 3, and Z is a moiety derived from a branched polyol and is preferably a moiety containing n branches ($n=n_1+n_2$), wherein each branch consists of a chain that includes ether linkages, e.g., a chain comprising not less than 3 repeating units (e.g., not less than 5 repeating units) which are preferably alkylene oxide units. More preferably, Z has the following structure (Formula 2):

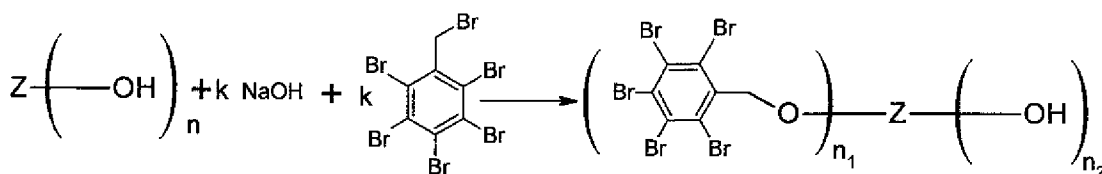


wherein R is selected from the group consisting of:

O-[(C₂-C₃)alkylene-O]_m and O-[CO-(C₂-C₅)alkylene-O]_m, m ≥ 3 (e.g., m ≥ 5), and n is an integer from 3 to preferably 6.

One convenient way for preparing the compounds of Formula 1 is illustrated by the reaction scheme depicted in Scheme 1:

Scheme 1:



Formula 1

$$n \geq 3$$

$$1 \leq k < n;$$

$$n_1 = 1, \dots, n-1$$

$$n_2 = n - n_1$$

wherein:

n_1 – indicates the number of pentabromobenzyl groups, and is an integer from 1 to $n-1$;

n_2 – indicates the number of hydroxyl groups, and is an integer from $n-1$ to 1; such that the total number of pentabromobenzyl groups and hydroxyl groups in the compound of the invention is not less than 3 (i.e., $n \geq 3$).

In the reaction scheme depicted in Scheme 1 above, Z-(OH)_n is the branched polyol starting material, with Z representing the branched part of the polyol consisting of a hydrocarbon backbone with n branches which are preferably chains having ether linkages. Preferably, Z has the structure of Formula 2, as shown above. As a polyol (Z-(OH)_n), it is preferred to use a polyol in which the number of hydroxyl groups is not less than 3, or a mixture of such polyols. According to one embodiment, the polyols to be used according to the present invention are polyether polyols. This class of polyols is obtained by the ring-opening addition reaction of one or more alkylene oxides (e.g., ethylene oxide and propylene oxide) with a suitable reactant containing active hydrogen atoms, such as alcohols, amines and acids; more specifically, said reactant may be selected from the group consisting of triols, novolac resins, pentaerythritol, sorbitol, sucrose, diethylenetriamine and the like. Polyester-polyols may also be used according to the present invention; this class of polyols is obtained by the condensation reaction of

dicarboxylic (or polycarboxylic) acid, such as adipic acid, phthalic acid or the like, with triols.

The novel compounds of the invention are useful as flame retardants. To reduce their viscosity, the new flame retardants may be used as a mixture with either a non-halogenated polyol, or a halogenated polyol, or a mixture thereof. More preferable are compositions of the new polymeric flame retardants with an ester of a pentavalent acid of phosphorus, namely, an ester of phosphoric acid. It is preferred to use for rigid polyurethane (PU) and polyisocyanurate (PIR) foams a halogenated, and more specifically, chlorinated alkyl phosphate esters. Particularly preferred are the triesters - trialkyl phosphates - such as tri(monochloroalkyl) phosphate or tri(dichloroalkyl) phosphate, with tris (2-chloropropyl)phosphate being especially preferred. The term "alkyl" preferably refers to a C₁-C₅ alkyl. It should be noted that the phosphate ester may be either symmetric or asymmetric, containing identical or different alkyl groups, respectively. It is preferred to use for flexible PU foams a halogen-free esters of phosphoric acid, and more specifically, butylated triphenyl phosphate esters. Particularly preferred is Phosflex 71 B, which is a mixture of t-butylphenyl diphenyl phosphate, bis(t-butylphenyl)phenyl phosphate, triphenyl phosphate and tri(t-butylphenyl) phosphate.

The composition of the novel compounds of Formula 1 with either halogenated or non-halogenated esters of phosphoric acid (or both), forms another aspect of the invention. The weight ratio between the compound of Formula 1 and the ester of phosphoric acid in the flame-retardant composition of the invention is between 1:9 and 9:1, e.g., the concentration of the (optionally halogenated) phosphoric acid ester relative to the total weight of the composition is preferably between 10 and 90%, and more preferably between 30 and 70%. Other brominated flame retardants, for example tribromoneopentyl alcohol (FR-513) may be included in the composition of the invention, such that the weight concentrations of the compound of Formula 1, the (optionally halogenated) phosphoric acid ester and tribromoneopentyl alcohol in the flame-retardant composition of the invention are in the ranges from 10 to 50 wt%, 10 to 50wt% and 10 to 50 wt%, respectively.

All the above and other characteristics and advantages of the invention will be better understood through the following illustrative and non-limitative detailed description of the preferred embodiments thereof.

Detailed Description of Preferred Embodiments

A mixture of pentabromobenzyl moiety-containing hydroxy-functional compounds of the present invention is prepared by the reaction of a pentabromobenzyl halide, preferably bromide (PBBBr) with a polyol (Scheme 1). It is preferred to use a polyol in which the number of hydroxyl groups is not less than 3, or a mixture of such polyols (or the corresponding metal alcoholate), in the presence or absence of a base.

Polyols used in the process for preparing the compounds of Formula I of the present invention include aliphatic polyether polyols having a molecular weight of 250-1000 or more and a functionality of 3 or higher, such as those employed in the polyurethane industry, especially glycerol-based polyether polyols, for example: Alcupol C-5710 – a glycerol initiated polyether polyol having a hydroxyl value of 250 mg KOH/g; Alcupol R-2510 – a glycerol initiated polyether polyol having a hydroxyl value of 570 mg KOH/g; Voranol 450 or Voranol 700 which are glycerol initiated polyether polyols having molecular weight of about 450 or 700, respectively.

In a preferred embodiment, the reaction of PBBBr and the polyol is carried out in the presence of a strong base such as sodium hydroxide or potassium hydroxide, in a medium of an organic solvent. The organic solvent is selected from aromatic compounds. Especially suitable aromatic solvents are xylene, chlorobenzene, ortho-dichlorobenzene, bromobenzene, mesitylene, and in particular, toluene.

The molar ratio between the polyol and the PBBBr is suitably adjusted such that at least one hydroxyl group of the polyol is replaced with PBBBr. It should be noted that the product may be in the form of a mixture, the components of which differ from one another with respect to the number of PBBBr and hydroxyl groups attached thereto (e.g. in the predominant component of the mixture n_1 equals 1 and n_2 equals 2, whereas in the minor component n_1 equals 2 and n_2 equals 1).

An effective amount of the base employed in the process is in a range of 1-1.2 mol per 1 mol PBBBr, and preferably 1.0-1.05 mol. The excess of base may lead to a side reaction to produce di-pentabromobenzyl ether.

The preferred reaction temperature is between 40 and 150°C, and preferably between 50°C and 80°C.

The base (e.g., sodium or potassium hydroxide) is preferably employed in a solid form. Water should be eliminated from the reaction mixture to prevent the side reactions of PBBBr with water to produce pentabromobenzyl alcohol.

It should be noted that the reaction may also be conducted without a base at a temperature of between 150°C and 250°C. However, in view of the fact that under such high temperatures the formation of undesired decomposition products may occur, it is generally preferred to carry out the reaction in the presence of a base.

Another aspect of the invention therefore relates to a process, which comprises reacting pentabromobenzyl halide, preferably bromide (PBBBr) with at least one polyol which contains not less than three hydroxyl groups, as described above. The process preferably comprises charging a reaction vessel with the polymeric polyol, a base and an organic solvent, heating the reaction mixture under reflux to remove water therefrom, adding pentabromobenzyl halide to the reaction mixture, maintaining same under heating and stirring to complete the reaction, and collecting the product of Formula 1.

The product is typically collected in the form of a mixture comprising two or more compounds of Formula 1, wherein in a first compound $n_1 \geq n_2$ and in a second compound $n_1 < n_2$. Such a mixture forms another aspect of the invention.

The novel compounds of the present invention are highly efficient flame retardants when incorporated into rigid or flexible polyurethane foams, polyisocyanurate (PIR) foams, polyurethane coatings, polyurethane adhesives and polyurethane elastomers. It should be noted that the compounds of the invention are useful over a broad Isocyanate Index (abbreviated herein MDI or TDI). The index refers to the ratio of isocyanate practically

used in the formulation vs. the theoretical stoichiometric amount of isocyanurate required, expressed in percents.

In view of the relatively high viscosity of the new bromine-containing polymeric flame retardants of the invention, these compounds are preferably used in the form of a mixture with less viscous halogen-free polyether polyols employed in the polyurethane industry.

Alternatively, the bromine-containing polyols of the invention can be used in the form of a mixture with less viscous halogen-free or halogen-containing alkyl phosphates such as tris-(chloropropyl) phosphate, tris-(dichloropropyl) phosphate or tris-(chloroethyl) phosphate.

The rigid polyurethane or polyisocyanurate foams contain a typical flame retardant amount of the composition of this invention. Typically, the compositions of this invention are used in amounts providing a total bromine concentration in the polymer in the range of 0.3 to 15 wt%, based on the total weight of the polymer. Preferably the total bromine concentration in the polymer is in the range 1 to 10 wt% and more preferably in the range of 2 to 5 wt%, based on the total weight of the polymer. Most preferably, the amounts used of the flame retardants of this invention are at least sufficient to meet the current requirements of the DIN 4102 B2 test.

The flexible polyurethane foams contain a typical flame retardant amount of the composition of this invention. Typically, the compositions of this invention are applied in amounts that provide a total bromine concentration in the polymer in the range of 0.3 to 15 wt%, based on the total weight of the polymer. Preferably the total bromine concentration in the polymer is in the range of 1 to 10 wt% and more preferably in the range of 1.5 to 5 wt%, based on the total weight of the PU polymer. Most preferably, the amounts used of the flame retardants of this invention are at least sufficient to meet the current requirements of the CAI Technical Bulletin 17 Section A

Examples

Example 1

Into a 1 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed a three-functional, glycerol-based polyether polyol with molecular weight ~1000 (500 g, 0.5 mol), NaOH (28 g, 0.7 mol) and toluene (700 ml). The mixture was heated under reflux (116°C) for 10 h until all the water was removed (~12 g). After that, the temperature was allowed to cool to 40°C. PBBBr (396 g, 0.7 mol) was added in portions. The mixture was vigorously stirred at 70°C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off, the toluene was evaporated and the product was washed with water 3 times at 70°C. After drying at 90°C under reduced pressure 792 g (~92% yield) of liquid product were obtained.

Total Br = 32.2%; OH number = 70.5 mg KOH/g.

Example 2

Into a 0.5 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed a three-functional, glycerol-based polyether polyol with a molecular weight ~300 (9.8 g, 33.3 mmol), KOH (3.7 g, 66 mmol) and toluene (300 ml). The mixture was heated under reflux (116 °C) for 1.5 h until all the water was removed. After that, temperature was allowed to cool to 90 °C. PBBBr (37.7 g, 66 mmol) was added in portions. The mixture was vigorously stirred at 90°C for 2.5 h until no PBBBr was detected (GC). After the PBBBr disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off and the toluene solution was washed with water 2 times. The solvent was evaporated under reduced pressure to give product (35.4 g, 84% yield).

Total Br = 58.3%, OH Number = 93.2 mg KOH/g.

Example 3

Into a 1 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed a three-functional, glycerol-based polyether polyol with molecular weight ~300 (180 g, 0.6 mol), NaOH (29.3 g, 0.73 mol) and toluene (550 ml). The mixture was heated under reflux (116°C) for 8 h until the water was

removed. After that, the temperature was allowed to cool to 40°C. PBBBr (407.5 g, 0.72 mol) was added in portions. The mixture was vigorously stirred at 70°C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off, the toluene was evaporated and the product was washed with water 3 times at 70°C. After drying at ~90°C under reduced pressure 476 g (~90% yield) of liquid viscous product were obtained.

Total Br = 56.3%; OH number = 102 mg KOH/g.

Example 4

Into a 1 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed a three-functional, glycerol-based polyether polyol with molecular weight ~300 (180 g, 0.6 mol), NaOH (28.1 g, 0.7 mol) and toluene (550 ml). The mixture was heated under reflux (116°C) for 8 h until the water was removed. After that, the temperature was allowed to cool to 40°C. PBBBr (391 g, 0.69 mol) was added in portions. The mixture was vigorously stirred at 70°C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off, the toluene was evaporated and the product was washed with water 3 times at 70°C. After drying at ~90°C under reduced pressure 462 g (~90% yield) of liquid viscous product were obtained.

Total Br = 56.9%; OH number = 100 mg KOH/g.

Example 5

Into a 1 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed a three-functional, glycerol-based polyether polyol with molecular weight ~300 (180 g, 0.6 mol), NaOH (30.5 g, 0.76 mol) and toluene (550 ml). The mixture was heated under reflux (116°C) for 8 h until the water was removed. After that, the temperature was allowed to cool to 40°C. PBBBr (424.5 g, 0.75 mol) was added in portions. The mixture was vigorously stirred at 70°C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off, the toluene was evaporated and the product was washed with water 3 times at 70°C. After drying at ~90°C under reduced pressure 441 g (~81% yield) of liquid viscous product were obtained.

Total Br = 55.4%; OH number = 98 mg KOH/g.

Example 6

Into a 0.5 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed glycerol based polyol with MW ~ 670 (Alcopol 2510, 67.3 g, 0.10 mol), NaOH (12.0 g, 0.3 mol) and toluene (200 ml). The mixture was heated under reflux (116 °C) for 3 h until all the water was removed. After that, the temperature was allowed to cool to 70 °C. PBBBr (145.8 g, 0.257 mol) was added in portions. The mixture was vigorously stirred at 70°C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off. The solvent was evaporated under reduced pressure to give the product (124 g, ~64% yield).

Total Br = 48.3%; OH number = 48.1 mg KOH/g.

Example 7

Into a 0.5 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed Alcopol 2510 (67.3 g, 0.10 mol), NaOH (8.0 g, 0.2 mol) and toluene (200 ml). The mixture was heated under reflux (116 °C) for 3 h until all the water was removed. After that, the temperature was allowed to cool to 70 °C. PBBBr (97.2 g, 0.17 mol) was added in portions. The mixture was vigorously stirred at 70 °C for 2.5 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off. The solvent was evaporated under reduced pressure to give the product (125 g, ~83% yield).

Total Br = 41.6%, OH number = 79.9 mg KOH/g.

Example 8

Into a 1 L flask fitted with a mechanical stirrer, thermometer, condenser, N₂ injector and Dean-Stark trap were placed glycerol based polyol (Voranol 3008) with MW ~3000 (300 g, 0.10 mol), KOH (12.3 g, 0.22 mol) and toluene (300 ml). The mixture was heated under reflux (116 °C) for 3.5 h until all the water was removed. After that, temperature was allowed to cool to 90 °C. PBBBr (113 g, 0.2 mol) was added in portions. The mixture was vigorously stirred at 90 °C for 2 h until no PBBBr was detected (GC). After the PBBBr had disappeared, H₃PO₄ was added to reach pH~7. The solid was filtered off and the toluene was evaporated under reduced pressure to give the product (221 g, ~60% yield).

Total Br = 11.6%. OH number = 22.9 mg KOH/g.

The application of the new compounds of the present invention is demonstrated through their use as flame retardants in standard formulations for rigid polyurethane foams (Examples 9-12), for rigid polyisocyanurate foams that have MDI Index of 200% (Examples 13-16), and for rigid polyisocyanurate foams with MDI Index of 350% - (Examples 17-20). In addition to the flame retardant, the following components were used in the preparation of the foams:

Polyol components used for PUR production:

1. Terol 516 - Polyester polyols having a hydroxyl value of 305 mg KOH/g.
2. Fox-O-Pol M530 - polyol having a hydroxyl value of 530 mg KOH/g.
3. Glycerol.

Polyol components used for PIR (200% index) production:

1. Terol 516 - Polyester polyols having a hydroxyl value of 305 mg KOH/g.
2. DEG - diethyleneglycol

Polyol components used for PIR (350% Index) production:

1. Kosa Terate 2541 - polyol having a hydroxyl value of 234 mg KOH/g.

Ancillary chemicals

DMCHA	dimethylcyclohexylamine
PMDETA	methylbis(2-dimethylaminoethyl)amine
Dabco K-15	catalyst
AM 58	trimerisation catalyst
DC 193	silicone surfactant
TCPP	tris(chloropropyl)phosphate
Pentane	blowing agent
Dabco TMR30	Amine catalyst
Tegostab B8460	silicone surfactant
Kosmos 75	catalyst (potassium-2-ethyl hexanoate)

Isocyanate

MDI- polymeric diphenylmethane diisocyanate

Examples 9 – 12**Process for preparing rigid polyurethane foams using the flame retardant compositions**

The procedure for the foam preparation was as follows:

The polyols, water, surfactant, flame retardant (abbreviated "FR" in the tables below) and catalysts were weighed and placed in a mixing beaker and mixed to form a homogeneous solution. To this solution was added pentane, and after additional mixing, the polymeric isocyanate. The mixture was stirred at 20°C under 3000 rpm for 6 sec and poured into another beaker. The foam that formed was kept for at least 24 hr at room temperature and then removed from the beaker and cut into test specimens with a saw. The samples were then tested for flammability according to the DIN 4102 B2 test procedure (a flame height of 15.0 cm or less means that the foam has passed the test). Table 1 summarizes the ingredients and parameters for the foam preparation and the results of the tests.

Table 1. Pentane-blown B2 continuous system (mixed at 20°C)

Composition (g)	Example 9	Example 10	Example 11	Example 12
M530	27	27	27	27
Terol 516	27	27	27	27
Glycerol	12	12	12	12
FR of Example 4/TCPP 70:30	40			
FR of Example 4/TCPP 60:40		40		
FR of Example 4/FR-513/TCPP 50:20:30			40	
FR of Example 4/FR-513/TCPP 50:10:40				40
TCPP	20	20	20	20
DMCHA	2	2	2	2
AM58	1	1	1	1
DC193	1.5	1.5	1.5	1.5
Water	2.49	2.49	2.49	2.49
Pentane	13.2	13.2	13.2	13.2
Total	146.19	146.19	146.19	146.19
Isocyanate, g (Urestyl-10)	175.42	173.61	176.99	174.6
Mix time, sec	6	6	6	6
Cream time, sec	12	11	11	12
Gel time, sec	33	32	30	32
Tack free time, sec	43	42	41	36
Cure time, sec	74	84	73	94
Br content in polyol mixture, wt%	10.9	9.4	11.8	9.8
Br content in foam, wt%	5.0	4.3	5.3	4.5
Flame height, cm (DIN 4102)	10.8	9.3	10.8	8.4

Examples 13-16**Process for preparing rigid polyisocyanurate foams (PIR, MDI Index 200%) using the flame retardant compositions**

The procedure for the foam preparation was as follows:

The polyols, water, surfactant, flame retardant and catalysts were weighed and placed in a mixing beaker, and mixed to form a homogeneous solution. To this solution was added pentane, and after further mixing the polymeric isocyanate, then the mixture was stirred at 20°C under 3000 rpm for 6 sec and poured into another beaker. The foam that formed was kept for at least 24 hr at room temperature and then removed from the beaker and cut into test specimens with a saw. The samples were then tested for flammability according to the DIN 4102 B2 test procedure (a flame height of 15.0 cm or less means that the foam has passed the test). Table 2 summarizes the ingredients and parameters for the foam preparation and the results of the testing of the foams.

Table 2. Pentane-blown B2 system (mixed at 20°C)

Composition (g)	Example 13	Example 14	Example 15	Example 16
Terol 516	100	100	100	100
DEG	5	5	5	5
FR of Example 4/TCPP 70:30	20			
FR of Example 4/TCPP 50:50		20		
FR of Example 4/FR-513/TCPP 50:20:30			20	
FR of Example 4/FR-513/TCPP 40:10:50				20
TCPP	40	40	40	40
PMDETA	0.5	0.5	0.5	0.5
K15	2	2	2	2
DC 193	1.5	1.5	1.5	1.5
Water	2	2	2	2
Pentane	14	14	14	14
Total	185	185	185	185
Isocyanate, g	241.9	239.6	243.34	240.36
Mix time, sec	6	6	6	6
Cream time, sec	10	12	12	13
Gel time, sec	42	48	47	48
Tack free time, sec	62	83	63	82
Br content in polyol mixture, wt%	4.2	3.1	4.7	3.3
Br content in foam, wt%	1.8	1.3	2.0	1.4
Flame height, cm (DIN 4102)	7.9	8.9	7.8	8.3

Examples 17-20**Process for preparing rigid polyisocyanurate foams with Index 350%**

The procedure is the same as in the previously described examples.

Table 3 summarizes the ingredients and parameters of the foam preparation and the results of the testing of the foams.

Table 3. Pentane-blown B2 system (mixed at 20°C)

Composition (g)	Example 17	Example 18	Example 19	Example 20
Kosa Terate 2541	100	100	100	100
FR of Example 2/TCPP 50:50	10			
FR of Example 7/TCPP 70:30		5		
FR of Example 6/TCPP 80:20			5	
FR of Example 6/TCPP 70:30				5
TCPP	10	15	15	15
DMCHA	1.5	1.5	1.5	1.5
Dabco TMR30	1	1	1	1
Tegostab B8460	1.5	1.5	1.5	1.5
Kosmos 75	1	1	1	1
Water	1	1	1	1
Pentane	13	13	13	13
Total	139	139	139	139
Isocyanate, g	252.63	250.92	251.6	251.46
Mix time, sec	6	6	6	6
Cream time, sec	9	9	9	9
Gel time, sec	36	28	34	39
Tack free time, sec	109	119	144	118
Br content in polyol mixture, wt%	2.1	1.07	1.39	1.2
Br content in foam, wt%	0.74	0.38	0.49	0.42
Flame height, cm (DIN 4102)	8.1	8.0	7.5	7.4

It should be noted that throughout the examples, the notation FR/TCPP or FR/FR-513/TCPP indicate a binary composition comprising FR of the invention and TCPP, or a ternary composition comprising FR of the invention, FR-513 and TCPP, respectively, with the weight ratios between the ingredients in the compositions being identified by the figures x:y or x:y:z.

Examples 21-23**Flexible polyurethane foams****Foam preparation procedure**

The low-density formulations set out in Table 4 below served for the preparation of the flame retardancy test foams in 45x45x30 cm cardboard boxes.

The raw materials and their relative amounts that were used for the foams preparation were:

Polyol Voranol 3008: 100 php

Flame retardant of the invention, blended with phosphated ester (Phosflex 71-B) at varying ratio - from 60/40 wt%, via 50/50 wt% and 40/60 wt%, down to 30/70 wt%, respectively: 16.0 php

Si surfactant Niax L-650: 1.0 php

Amine catalyst blend Dabco 33LV/BDE at a ratio of 3/1: 0.23 php

Blowing agent MeCl₂: 10 php

Tin catalyst T-9: 0.30 php

TDI (Index 110%): 71.1 php

All the ingredients, apart for the water and TDI, were successively weighed and added in the above given order, into 4 l disposable cup. The mixer was then stirred at 2100 rpm for 20 sec, then pre-weighed water was injected through a syringe, while stirring, into the cup and stirring continued for another 20 sec. Pre-weighed TDI was then added and the stirring continued for another 7 sec after which the mixture was poured into the box and allowed to rise. Foams were left for 48 hours in a hood to cure before any further processing.

Flammability test results in flexible polyurethane foams

The flame retardancy was tested in low density foams (1.03 pounds per cubic feet). After 48 hours of curing in the hood, samples were cut and conditioned according to the specifications of the CAL 117A TB for flammability test.

The brominated polymeric flame-retardant of the invention of Example 3 was used in the foams preparation.

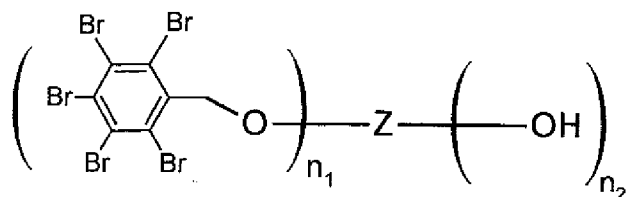
Table 4 presents the average char length of the test following different sample conditioning terms, vs. the composition of the brominated polymeric flame retardant blend in phosphated ester (Phosflex 71-B).

Table 4: CAL 117A test results of flexible low-density polyurethane foams, flame-retarded with brominated polymeric FR of the invention, applied blended with phosphated ester

Example	Blend composition: Br-Polymeric FR / Phosflex 71-B, ratio	Blend load, php	CAL 117A	
			Average char length, cm	
			104°C conditioning	22°C, 50% R.H. conditioning
21	40 / 60	16.0	9.5	9.6
22	35 / 65	16.0	8.9	8.7
23	30 / 70	16.0	9.6	9.9

Claims

1. A compound of Formula 1:



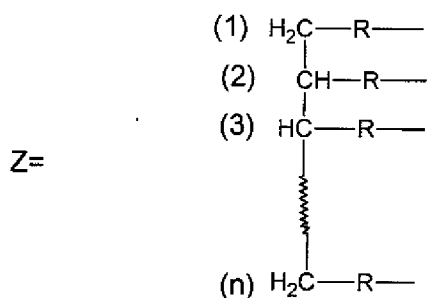
Formula 1

wherein each of n_1 and n_2 is an integer equal to or greater than 1, with their the sum (n_1+n_2) being equal to or greater than 3, and Z is a moiety derived from a branched polyol which contains (n_1+n_2) branches.

2. A compound according to claim 1, wherein Z is a branched hydrocarbon having (n_1+n_2) branches, said branches comprising ether linkages, with the molecular weight of Z being between 150 and 3000 Da.

3. A compound according to claim 1, wherein Z is a moiety containing n branches ($n=n_1+n_2$), wherein each branch is a chain comprising not less than 3 repeating units which are alkylene oxide units.

4. A compound according to claim 3, wherein Z has the following structure (Formula 2):



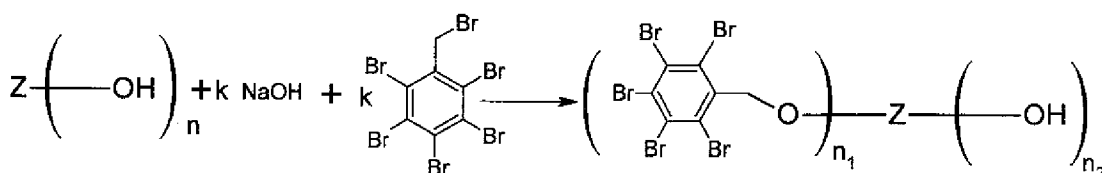
wherein R is selected from the group consisting of:

$\text{O}-[(\text{C}_2-\text{C}_3)\text{alkylene-O}]_m$ and $\text{O}-[\text{CO}-(\text{C}_2-\text{C}_5)\text{alkylene-O}]_m$, $m \geq 3$, and n is an integer from 3 to 6.

5. A mixture comprising two or more compounds of Formula 1 as defined in any one of claims 1 to 4, wherein in a first compound $n_1 \geq n_2$ and in a second compound $n_1 < n_2$.

6. A process for preparing the compound of Formula 1 as defined in claim 1, comprising reacting pentabromobenzyl halide with at least one branched polyol of the formula $Z(OH)_n$, which contains n branches with n terminal hydroxyl groups ($n \geq 3$), optionally in the presence of a base.

7. A process according to claim 6, wherein the pentabromobenzyl halide is pentabromobenzyl bromide, said process being carried out in the presence of a base which is either sodium hydroxide, potassium hydroxide or a mixture thereof, according to the following reaction scheme:



wherein n , n_1 and n_2 are as defined above, k is an integer such that $1 \leq k < n$ and NaOH represents the base.

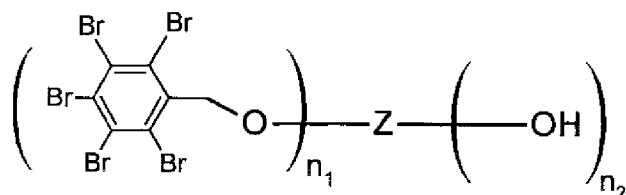
8. A process according to claim 6, wherein the branched polyol $Z(OH)_n$ has molecular weight of between 250 and 3000 Da.

9. A process according to claim 8, wherein the branched polyol $Z(OH)_n$ comprises glycerol-based polyether polyol.

10. A process according to any one of claims 6 to 9, comprising charging a reaction vessel with a branched polymeric polyol, a base and an organic solvent, heating the reaction mixture under reflux to remove water therefrom, adding the pentabromobenzyl halide to the reaction mixture, maintaining same under heating and stirring to complete the reaction, and collecting the product of Formula 1.

11. Use of the compound(s) as defined in any one of claims 1 to 5 as a flame retardant.

12. A flame retardant composition comprising the compound(s) of Formula 1 as defined in any one of claims 1 to 5 and at least one ester of phosphoric acid.
13. A flame retardant composition according to claim 12, which further comprises tribromoneopentyl alcohol.
14. A fire retarded polymeric or polymer-containing composition comprising a unit derived from pentabromobenzyl alkyl ether of the formula:



wherein Z, n_1 and n_2 are as defined in claim 1.

15. A fire retarded composition according to claim 14, wherein the polymer is selected from the group consisting of flexible polyurethane, rigid polyurethane and polyisocyanurate foams.
16. Flexible polyurethane foams flame-retarded with the pentabromobenzyl moiety containing hydroxy-functional compounds as defined in any one of claims 1 to 5.
17. Rigid polyurethane foams flame-retarded with the pentabromobenzyl moiety containing hydroxy-functional compounds as defined in any one of claims 1 to 5.
18. Polyisocyanurate foams flame-retarded with the pentabromobenzyl moiety containing hydroxy-functional compounds as defined in any one of claims 1 to 5.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2012/000356

A. CLASSIFICATION OF SUBJECT MATTER IPC (2012.01) C09K 21/08, C09K 21/14, C07C 43/178, C07C 49/245, C08G 18/02, C08G 71/04 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC (2012.01) C09K 21/08, C09K 21/14, C07C 43/178, C07C 49/245, C08G 18/02, C08G 71/04 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: SCIRUS, THOMSON INNOVATION, Google Patents, CAPLUS, REGISTRY Search terms used: polyol , glycerol , alcohol , polyurethane , polyisocyanurate , pentabromobenzyl , fire retarded , flame retardant		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2005118720 A1 ALBEMARLE CORP [US] SJERPS RINUS [BE] 15 Dec 2005 (2005/12/15) Para 0012 , claim 1	1-5
Y	US 4067911 A WALRAEVENS RENE; COLLIN ANDRE 10 Jan 1978 (1978/01/10) column 1 lines 57-61	11-18
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 02 Jan 2013		Date of mailing of the international search report 02 Jan 2013
Name and mailing address of the ISA: Israel Patent Office The Technology Park, Bldg.5, Malcha, Jerusalem, 96951, Israel Facsimile No. 972-2-5651616		Authorized officer BERKOWITZ Tzipora tziporab@justice.gov.il Telephone No. 972-2-5651656

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