UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 11 1986

MEMORANDUM

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

SUBJECT: Data Needs Paper for the Acrylate/Methacrylate Chemical Category

FROM: William Farland, Ph.D.
Acting Director
Health and Environmental Review Division (TS-796)

TO: David Dull
Acting Director
Chemical Control Division (TS-794)

Attached is HERD's proposal for the health and environmental effects section of the Testing Recommendations/Data Needs for the Acrylate/Methacrylate chemical category. We view this proposal as the basis for beginning negotiations with industry and other groups interested in testing chemicals in this category. Clearly many of the details of the testing plan still need to be determined. We expect that these testing details will be discussed further and resolved once negotiations with the various interested parties begin. We also believe that the data needs discussions and negotiations should be undertaken in conjunction with discussions on our evaluation of the available toxicity data on this category as presented in our earlier Position Paper.

In preparing our data needs proposal we have made several assumptions and identified several considerations that should be made clear as our proposal is incorporated into the regulatory strategy for the acrylate/methacrylate chemical category. First, and perhaps most importantly, our testing proposal is designed to provide a better understanding of the health and environmental effects of the acrylate/methacrylate category as a whole. Our testing proposal may not necessarily provide the basis for conducting quantitative risk assessments on specific members of the category. We are viewing this proposal not in relation to a particular section of TSCA, but as a means of qualitatively prioritizing OTS concerns for the spectrum of chemicals within this broad category for use under all Sections of TSCA. This proposal must be viewed in the context of answering some basic, broad questions on the hazards identified with the category which will significantly improve our ability to assess these chemicals in the various regulatory processes of TSCA. The data from this testing will focus our regulatory emphasis on those chemicals that are likely to present the greatest hazard.

The second major consideration in our testing proposal is the general lack of risk and economic considerations in our proposal. Our proposal reflects primarily a hazard-based perspective for identifying needed testing. We have not attempted to prioritize the testing in our proposal with other types of testing that may be deemed desirable for the category (e.g. epidemiology, fate, and exposure). These types of priorities need to be considered as an Office-level decision.

Also, in our proposal we have generally not considered the relative risk from the identified hazards of these chemicals because neither the exposure nor the dose-response information is available at this time to quantitatively evaluate these risks. Without a good measure of the relative hazard posed by members of the category, it is not possible now for us to explicitly consider relative risk when determining the general nature or scope of our testing proposal. Higher risk chemicals (or categories) might, for example, warrent more extensive or rigourous testing than lower risk chemicals (or categories). It may be best to address this issue as an Office-level policy decision where a more comprehensive view of exposure and relative risk can be considered. In this forum, additional information (e.g., exposure and economics) may be available to help balance our hazard-based testing proposal against other types of testing needed for the category and against the relative risk of these chemicals. These Office-level policy decisions may require modifications to our attached testing proposal.

The third major consideration in our proposal is related to the sequence of testing for the four areas of testing that we have identified (absorption, carcinogenicity, neurotoxicity, and ecotoxicity). We suggest that the four areas not be combined into a tiered scheme. Each area can be pursued as a separate line of investigation. However, it may be logical to do the absorption testing early in the program, since this testing should provide better insights into the limits of our health concerns for the larger molecular weight category members.

We have also proposed a general approach for the other health effects testing. For the neurotoxicity testing we expect that repeating the existing tests should be done first to confirm these results before a broader range of chemicals is tested to answer our basic category questions. In the carcinogenicity testing area we have identified the need for genotoxicity data, modified bioassay data, and data from complete bioassays. Work on expanding the genotoxicity data base is currently underway at the EPA lab at RTP. We believe that work to develop data in both an acceptable modified and a standard bioassay should be started together. We are recommending that OTS use the data, accepting the validity of both positive and negative results, developed in the modified bioassay as it becomes available for regulatory decision-making and for identifying additional chemicals to be tested in the complete bioassay. This modified bioassay data should only be accepted, however, if data are simultaneously developed in a standard bioassay. The standard bioassay results, that we expect will take longer to develop, would then be used to validate the modifed bioassay design and the genotoxicity tests in addition to providing a more scientifically acceptable way of evaluating the carcinogenic potential of the category members.

Attachment

cc:

W. Farland	J. Du	J. DeSantis	S. Irene
M. May	J. Gilford	D. Klauder	A. Blaschka
D. Beal	G. Timm	P. Hayes	J. Merenda
B. Means	V. Nabholz	E. Falke	K. Dearfield
V. Turner	M. Townsend	D. Gould	T. Jones
A. Auletta	M. Argus	R. Brink	C. Auer

TESTING RECOMMENDATIONS/DATA NEEDS FOR THE ACRYLATE/METHACRYLATE CHEMICAL CATEGORY

I. Introduction

The HERD Position Paper, The Health and Environmental Effects of Acrylate and Methacrylate Chemicals and the Acrylate/Methacrylate Category, presents an evaluation of the available toxicity information on this category of chemicals and attempts to identify those areas where the data are limited or nonexistant. Questions about the nature of the existing toxicity information should be directed to the "Position Paper", since the present paper does not reexamine all this information. The purpose of the "Data Needs Paper" is to more clearly identify the important areas of uncertainty or data gaps encountered during toxicity assessments of chemicals in this category and to propose a testing strategy that will reduce the uncertainty of these assessments. It is expected that this testing proposal will serve as an initial basis to begin negotiations with interested parties. Further discussion with these parties will clarify and possibly modify this proposal.

Based on the available toxicity data, there is a clear need for additional testing of members of the acrylate/methacrylate category. The current data base, while providing the basis for identifying several toxic effects of concern to the Agency, is relatively limited with respect to predicting the relative hazard for the entire spectrum of chemicals that fall within this category. Because of the relatively limited nature of the database, decisions on chemicals in the category are often made based on extrapolations and generalizations from the available data. These extrapolations and generalizations lead to large uncertainties in our decisions.

HERD believes that the proposed testing will significantly improve our understanding of the relative toxicity of chemicals in this category and more accurately define the scope of the category for which toxicity concerns exist. Specifically we

expect the test results to reduce the uncertainty of our assessments in several areas. These areas include: (1) a better basis for determining the likelihood of human absorption of these chemicals (i.e., defining the limits of our health concerns), (2) providing a measure of the relative hazard for various subsets of the category, and (3) helping prioritize our concerns for these chemicals for more detailed testing and regulatory activity. To reduce the uncertainty of our assessments in these areas we expect the testing results to answer some fundamental questions about the toxicity of this category. These questions include:

1. What toxic effects are generally identified with chemicals in this category?

2. What is the relative hazard of acrylates vs. methacrylates for these toxic effects?

3. What is the relative hazard of mono vs. multifunctional members for these toxic effects?

4. What is the relative hazard of the larger molecular weight vs. smaller molecular weight members?

5. What physico-chemical factors have the greatest affect on the dermal absorption of these chemicals and what is the relationship between these factors and the dermal absorption rate for these chemicals?

6. What is the importance of the exposure route in eliciting the health effects of these chemicals?

While the answers to these questions will significantly improve our understanding of the toxicity of this category of chemicals, they may not necessarily provide the basis for conducting quantitative risk assessments on specific category members. Different or supplementary testing may also be needed to support quantitative risk assessment decisions.

Based on the identified data gaps and uncertainties in our assessments, we are proposing testing in four basic areas. These areas include:

1. Bioavailability/Absorption - Because our understanding of the bioavailability of acrylates/methacrylates is limited, OTS has been forced to rely on the qualitatively observed absorption potential of specific category members as an approximation of the general bioavailability of all category members. In practice, this has resulted in our using the molecular weight (MW) of a category member as the measure of its absorption potential. To do this we have assumed an inverse relationship between MW and absorption potential for category members. Empirical evidence is very limited for establishing a particular molecular weight above which absorption does not occur or is not biologically significant and for understanding the influence of other physico-chemical factors (e.g., water solubility) on the absorption potential of these chemicals. Systematically testing acrylates and methacrylates in a manner which provides for careful control of physico-chemical properties would immediately help to identify the most important factors and the relationships between these factors and the absorption potential of category members. This would be a large step toward more empirically defining the extent or limits of our health concerns for category members.

2. Carcinogenic Hazard Potential - Some members of this category have produced a carcinogenic response in laboratory animals. However, the relationship between chemical structure and this response is unknown because of the relatively few category members actually tested. Also, it is difficult to compare the available test results because few of the tests were conducted using the same protocol. Additional testing would help define the relationship between chemical structure and the inherent carcinogenic activity of category members and assist in validating screening tests designed to measure this carcinogenic activity more quickly and more economically. Concurrent testing in a standard 2-year bioassay and in an appropriate experimental modified bioassay would be critical to meeting these objectives.

3. Neurotoxic Hazard Potential - The neurotoxicity concern for this category is based on a very limited data set. Therefore, the basis for identifying this hazard with this category is weak. As a first step, HERD believes the existing neurotoxic effect data should be confirmed by repeating the tests that showed this effect by both the previously used routes of exposure and by the route of expected human exposure. Depending on the results, a broader range of category members might need to be tested to determine the relative neurotoxic potential of chemicals in the category.

4. Ecotoxic Hazard Potential - The available ecotoxicity hazard data on category members is limited to acute tests. Some category members have LC_{50} values around 1 mg/L and show signs of chronicity, suggesting that chronic exposures would produce toxic effects at concentrations much lower than acute exposures. Additional testing on a broader range of category

members would focus our concerns on particular subsets or individual category members by providing data needed for establishing a quantitative structure activity relationship (QSAR) and by determining the relationship between acute and chronic toxicity values for this category of chemicals.

II. Proposed Testing Plans

A. Bioavailability/Absorption

1. Data Gaps

HERD has identified three basic data gaps in our understanding of the bioavailability/absorption potential of fluid acrylate/methacrylate esters. The existance of these data gaps has forced us to make certain assumptions about the bioavailability/absorption of these chemicals that should be evaluated with additional testing. This is an important area for testing because absorption potential is usually the first area examined during the evaluation of category members in the new chemical process. If, based on a member's physical form and physico-chemical parameters, absorption is not considered likely, then the various health hazards are not expected to be associated with that chemical.

The acrylate/methacrylate generic SNUR incorporates an absorption-based, molecular weight definition of the category which places limits on the Agency's health concerns for the category. In establishing this category definition and in assessing the bioavailability/absorption potential of individual category members, the following assumptions have been made:

a) MW is inversely related to the absorption potential of category members and can be used as an approximation of absorption potential. Other physico-chemical factors such as water solubility and octanol/water partition coefficient may also affect this relationship and should be evaluated.

b) Absorption by the dermal or oral routes is expected to decrease with increasing molecular weight in a manner such that at a molecular weight of 1000 or greater the absorption potential of any category member can be considered negligible.

c) Acrylate/Methacrylate esters with a MW of 500 or less are expected to be absorbed to a significant degree when present at concentrations of 2% or greater in fluid acrylate/methacrylate substances having a number average molecular weight of greater than 1000.

2. Testing Proposal

Our testing proposal is designed to determine the relationship between physico-chemical factors and bioavailability/absorption potential of these chemicals. It is focused on providing information to evaluate the assumptions stated above that have been part of our decision-making approach to assessing chemicals in this category. The test plan is also focused on dermal absorption because this is the most frequently identified exposure route during new chemical assessments. Our testing proposal includes three components:

a) To test the effect of molecular weight on the absorption of acrylates and methacrylates, a homologous series of acrylates and methacrylates could be synthesized where only the size and MW are varied with a repeating unit. For example, a series of radiolabeled polypropylene glycol diacrylates (PGDA) could be synthesized with a range of propylene glycol units (=n). The smaller size members of the series would be expected to be absorbed more readily than the larger members of the series. The chemicals should be dermally tested neat with a closed patch. Measurements of radioactivity should be made in urine samples and samples of subcutaneous tissues at the site of application. A sufficient number of members in the series should be tested to define the relationship between MW and absorption. Ideally, enough larger MW members should be tested to identify a plateau or asymptote where further increases in MW do not significantly reduce absorption. Selected methacrylate esters should then be tested to determine any differences in absorption between acrylates and methacrylates.

b) Once the general relationship between MW and absorption has been established for acrylates and methacrylates, the effect of varying water solubility and octanol/water partition coefficient at a given MW should be evaluated. This might be done by comparing the absorption of PGDA and a more water soluble polyethylene glycol diacrylate of similar MW.

c) We also propose testing to evaluate the importance of concentration in assessing absorption potential of low MW acrylates/methacrylates from a fluid high acrylate/methacrylate material. For example, radio-labeled neopentyl glycol diacrylate (NPGDA, MW=212) could be synthesized and tested neat in the same protocol as above to establish its relative absorption in this test. A large PGDA-n could also be synthesized with n such that the chemical will have only negligible absorption using the protocol stated above. The labeled NPGDA could then be mixed with the PGDA-n at concentrations above, below, and at 2% and the absorption of labeled NPGDA measured in the protocol listed above.

A determination of a reasonable cutoff for the percent of low MW species in high MW acrylate/methacrylate substances could then be based on this absorption data.

3. Data Use

The results of these tests will provide a better basis for:

(a) Understanding the relationship between MW and absorption.

(b) Identifying other physico-chemical factors that significantly affect the absorption of these chemicals.

(c) Understanding the absorption potential of lower MW constituents in a higher MW mixture.

(d) Defining the range of physico-chemical factors for category members beyond which we expect that acrylate/methacrylate chemicals will not be absorbed to a significant degree and thus will not pose a health risk to humans.

These data will be used to provide an empirical basis for defining the range of category members that should be expected to be absorbed by humans and that may present a health risk to humans. Acrylates or methacrylates with physico-chemical properties outside the category limit will not be expected to be absorbed to a significant extent by humans and, therefore, should not be expected to present a health risk to humans. When combined with more detailed information on the potential health effects, an improved understanding of the absorption of these chemicals will eventually also improve our ability to assess the relative risk of specific category members.

B. Carcinogenic Hazard Potential

1. Data Gaps

Based on our review of the available data on the carcinogenicity of category members, there are two basic data gaps associated with a category-wide understanding of the carcinogenicity of acrylates/methacrylates. First, the available test data were generated from a chemical specific perspective and do little to help answer our basic questions about the category as a whole. For example a measure of the relative carcinogenic hazard of acrylates vs. methacrylates, mono vs. multifunctionals, and the larger vs. smaller MW category members cannot be generated from the existing data. Second, the available data were derived from significantly different protocols, making

comparisons of the results difficult. We are currently unable to determine how reliable the available modified bioassay studies are in detecting the inherent carcinogenic potential of these chemicals. Therefore, one of the objectives of a testing program for this category should be the validation of a modified bioassay which could be used to economically screen chemicals containing the acrylate/methacrylate functional groups for their potential carcinogenicity. To most effectively accomplish this objective, results generated in a standard 2-year bioassay on a carefully selected series of category members should be compared with the results from an appropriate modified bioassay on a more extensive set of category members. The data generated in both assays will be useful in describing the relative carcinogenic hazard of chemicals within the category.

2. Testing Proposal

Currently there are no validated in vitro or in vivo carcinogenicity screening tests for this category of chemicals. Therefore, the most scientifically acceptable way to evaluate the inherent carcinogenic potential of category members is to test them in a standard two-year bioassay. A validated screening tool would be a valuable tool to help answer questions about the relative carcinogenic hazard of the category and for screening the carcinogenic potential of "new" category members. As a result, there is a need for developing data from both a standard bioassay and a screening assay. EPA is currently developing data from genotoxicity assays for this category, so our testing proposal focuses on data development from both the standard bioassay and a modified, screening bioassay.

Because of the category approach to evaluating these chemicals, HERD proposes the concurrent development of data in an acceptable modified bioassay protocol and ine a standard bioassay. The results of the modified bioassay would provide a cost-effective basis for evaluating and screening a range of category members, whereas the results of the standard bioassay would be used to validate the design of the modified bioassay.

The specific protocol design for both the modified and standard bioassays for this testing should be developed in consultation with interested parties. We believe the main uncertainty in the design of these tests is the route of administration for the test substance. Inhalation does not appear appropriate because only low doses can be administered, and drinking water studies would be complicated by hydrolysis of the test substance. For human risk assessment purposes, the primary route of expected human exposure (dermal for this category) should be used. However, because of the irritating properties of category members it may be difficult to reach an appropriate MTD by this route or to generate a dose-response curve by testing over a range of doses. The dermal route has, however, yielded several positive results in single dose, limited bioassays. The gavage route, while not the route of human exposure does have certain advantages over the dermal route in this case. First, the gavage route allows higher doses to be administered in a more precise manner. Second, dosing by gavage can be done more frequently. Third, irritation appears to be less of a problem with the gavage route, but it is still a major difficulty. However, the gavage route is clearly not the expected route of human exposure.

In addition to determining the route of exposure for both a modified and the standard bioassays, several other important aspects of the modified bioassay need to be defined to ensure it is an acceptable test. These factors include: the amount of histopathology, the study duration, number of animals, etc. The major consideration in defining these details will be the trade-off between the sensitivity of the test and the test cost. The use of statistical analyses may help in evaluating the effect of the various test options on the power of the modified bioassay protocol.

The selection of specific chemicals for testing will also need to be resolved following further discussions with the interested parties. Tables 1 and 2 present a list of category members from which those to be tested could be selected. The specific chemicals selected should be designed to answer our basic questions about the category and to maximize the use of the available data and resources.

3. Data Use

The most important use of this data will be to provide the Agency with a data set that accurately represents the inherent carcinogenic potential of the tested category members. These data will provide the basis for distinguishing the relative carcinogenic activity of subsets of this category by providing a reasonable degree of confidence that negative results indicate a true lack of carcinogenic activity. These data will also provide an acceptable basis or baseline for validating modified bioassay and genotoxicity test results that may be useful to screen a wider range of "existing" and "new" acrylate/methacrylate chemicals. These results will enable us to focus our attention on those members or subsets of the category that present the greatest carcinogenic hazard.

C. Neurotoxic Hazard Potential and Other Chronic Effects

1. Data Gaps

The available neurotoxicity hazard data for this category of chemicals is very limited. It consists primarily of one study on 2-hydroxyethyl acrylate (2-HEA), one study on a methacrylate mixture, and several case reports of methacrylate exposures to humans. Neurotoxicity effects have been observed in so few studies that extrapolation to the entire category is not possible with a reasonable degree of certainty. Two basic

data gaps are apparent from our evaluation of the available data.

a) Because it is possible that the positive neurotoxicity results reported are false positives, there is a need to retest the chemicals previously studied with a standard protocol to confirm the existence of the neurotoxic effect.

b) Given the confirmation of the neurotoxic effects for the previously tested chemicals, a wider range of category members would then be tested. These additional tests will help answer questions about the relative neurotoxic hazard within the various subsets of the category (e.g. acrylates vs. methacrylates, mono vs. multifunctional, larger MW vs. smaller MW members).

In addition to evaluating neurotoxic effects in these studies, it would be valuable to also look for any other chronic effects (non-carcinogenic). The available data that specifically included observations for other effects are very limited for this category, although no other specific effects have been noted in the available studies.

2. Testing Proposal

The neurotoxicity testing should be a tiered approach designed to first confirm the available results, and then to develop additional data if the first tier is positive.

a) As the first proposed tier of testing, 2-HEA should be retested in a 90-day subchronic study using the OTS text guidelines on

the functional observational battery and neuropathology. Also, methyl methacrylate, pentaerythritol triacrylate, trimethylol propane trimethyacrylate, trimethylol propane triacrylate, and tripropylene glycol diacrylate should be tested in a 90-day subchronic study to confirm the reported neurotoxic effects for these chemicals. The route of exposure should be identified based on many of the same considerations identified in the carcinogenicity discussion.

b) If a neurotoxic effect can be confirmed in at least some of the studies listed above, additional studies should be performed. These additional studies should involve a 90-day subchronic protocol using OTS test guidelines on the functional observational battery and neuropathology. Chemicals for testing should be selected from Tables 1 and 2 to help answer questions of the relative hazard of acrylates vs. methacrylates, mono vs. multifunctionals, and the larger MW vs. smaller MW category members and to maximize the use of the available data on this effect. Signs of other chronic (non-carcinogenic) effects should be assessed in all the neurotoxicity studies.

3. Data Use

The results of the testing proposal will be used by the Agency in several ways. First, it will allow us to confirm or reject the identification of a neurotoxicity hazard with this category of chemicals. Second, if this hazard identification is confirmed it will allow us to prioritize our concerns for a wider range of category members by identifying

those that present the greatest hazard. Third, it will help identify other chronic effects, if any, that should be associated with this category of chemicals.

D. Ecotoxic Hazard Potential

1. Data Gaps

The available ecotoxicity data on this category of chemicals are primarily from acute toxicity tests. These results indicated acute LC_{50} values as low as 1 mg/L and indicated signs of chronicity, which suggests that chronic effect concentrations may be much lower (one-twentieth or less) than acute effect concentrations. These data, which identify an ecotoxicity hazard concern, require further evaluation to answer some basic questions about the nature of the effect for a wider range of category members. These questions include the relative hazard of acrylates vs. methacrylates, mono vs. multifunctionals, smaller MW vs. larger MW members, the effect of acrylate equivalent weight (i.e., total MW divided by the number of acrylate functional groups), and the effect of other functional groups. Testing on fish, daphnia, and algae is also needed to evaluate the relative sensitivity among the basic groups of aquatic organisms.

2. Testing Proposal

Our ecotoxicity testing proposal involves the selection of acrylate chemicals from Table 2 and methacrylate chemicals from Table 3 in addition to larger prepolymers ($MW \leq 1000$) that will answer our basic questions identified above. It is proposed that each chemical selected be tested in an acute fish, acute daphnid, and algal toxicity tests. If the 96-hour EC_{50} value for fish or the 48-hour EC_{50} value for daphnids is less than 1 mg/L then the appropriate chronic toxicity testing should be done. However, if

the acute EC_{50} values are greater than 1 mg/L but less than 100 mg/L and there is evidence of cumulative toxicity (i.e., the fish 24-hour EC_{50}/96-hr EC_{50} ratio or the daphnid 24-hour EC_{50}/48-hour EC_{50} ratio is greater than two), then the proposed chronic toxicity testing should also be done. The proposed chronic toxicity testing is the fish early life stage toxicity test and the daphnid chronic toxicity test.

3. Data Use

These data will allow the Agency to develop a QSAR between acute toxicity and physico-chemical properties, to determine whether certain functional groups or category subsets present a greater or lesser aquatic toxicity hazard, and to determine the limits of our aquatic toxicity concern for the category based on MW, acrylate equivalent weight, and water solubility. This will allow us to focus our attention on those category members that appear to present the greatest ecotoxcity hazard.

Table 1. Acrylate candidates for health and ecotoxicity testing.

ACID

acrylic acid

MONOACRYLATES

methyl acrylate
allyl acrylate
propyl acrylate
n-butyl acrylate
pentyl acrylate
n-octyl acrylate
2-ethylhexyl acrylate
decyl acrylate
dodecyl acrylate

CYCLIC MONOACRYLATES

phenyl acrylate
benzyl acrylate
isobornyl acrylate

HYDROXY-SUBSTITUTED MONOACRYLATES

Hydroxypropyl acrylate

ALKOXIDE-SUBSTITUTED MONOACRYLATES

methoxy acrylate
butoxyethyl acrylate

PHENOXIDE-SUBSTITUTED MONOACRYLATES

phenoxyethyl acrylate

EPOXY-SUBSTITUTED MONOACRYLATES

glycidyl acrylate

NITRO-SUBSTITUTED MONOACRYLATES

2,2-dinitropropyl acrylate

AMINO-SUBSTITUTED MONOACRYLATES

dimethylaminoethyl acrylates

CYANO-SUBSTITUTED MONOACRYLATES

2-cyanoethyl acrylate

Table 1. (continued)

HALOGENATED MONOACRYLATES

2,3-Dichloropropyl acrylate
tribromophenyl acrylate
2,2,2-trifluoroethyl acrylate
3,3,4,4,4-pentafluorobutyl acrylate
nonafluorohexyl acrylate
tridecylfluorooctyl acrylate
heptadecylfluorodecyl acrylate
pentacosafluorotetradecyl acrylate

POLYACRYLATES

ethyleneglycol diacrylate
1,4-butanediol diacrylate
diethyleneglycol diacrylate
1,6-hexanediol diacrylate
tetraethyleneglycol diacrylate

trimethylolpropane triacrylate

pentaerythritol tetraacrylate

dipentaerythritol pentaacrylate

Table 2. Methacrylate candidates for health and ecotoxicity testing.

ACID

methacrylic acid

MONOMETHACRYLATES

methyl methacrylate
allyl methacrylate
propyl methacrylate
butyl methacrylate
2-ethylbutyl methacrylate
octyl methacrylate
ethylhexyl methacrylate
n-decyl methacrylate
lauryl methacrylate

CYCLIC MONOMETHACRYLATES

phenyl methacrylate
benzyl methacrylate

HYDROXY-SUBSTITUTED MONOMETHACRYLATES

Hydroxypropyl methacrylate

ALKOXIDE-SUBSTITUTED MONOMETHACRYLATES

methoxyethyl methacrylate
2-(vinyloxy)ethyl methacrylate

PHENOXIDE-SUBSTITUTED MONOMETHACRYLATES

2-phenoxyethyl methacrylate

EPOXY-SUBSTITUTED MONOMETHACRYLATES

glycidyl methacrylate

NITRO-SUBSTITUTED MONOMETHACRYLATES

2,2-dinitropropyl methacrylate

AMINO-SUBSTITUTED MONOMETHACRYLATES

N,N-dimethylaminoethyl methacrylates

CYANO-SUBSTITUTED MONOMETHACRYLATES

2-isocyanotomethyl methacrylate

Table 2. (continued)

HALOGENATED MONOMETHACRYLATES

2-chloroethyl methacrylate
trifluoroethyl methacrylate
2,2,3,3,3-pentafluoropropyl methacrylate
3,3,4,4,5,5,6,6-nonafluorohexyl methacrylate
1H,1H-pentadecafluorooctyl methacrylate

POLYMETHACRYLATES

ethyleneglycol dimethacrylate
1,3-butanediol dimethacrylate
diethyleneglycol dimethacrylate

aluminum trimethacrylate

ADDITIONAL METHACRYLATES

tributyltin methacrylate
3-(trimethoxysilyl) propyl methacrylate
thioglycidyl methacrylate
vinyl methacrylate