

# 北京地区臭氧层损耗、气溶胶污染 与紫外辐射的变化

王少彬

(中国科学院生态环境研究中心, 北京 100085)

**摘要** 对北京地区臭氧层损耗和气溶胶污染对紫外辐射量变化的影响进行了计算。结果表明,当臭氧总量减少 1%—30% 时,UV-B 对 DNA 危害效应的辐射放大因子(RAF)从 2.3 增加到 4.2。城区和乡村环境的气溶胶污染使 UV-B 日辐射总量分别降低 45% 和 10%。如果仅考虑臭氧总量的变化,1980—1989 年间 UV-B 辐射量年变化率为 1.4%,当考虑气溶胶因素的变化后,UV-B 辐射量年变化率为 -0.7%,这与实际观测的结果相符合。

**关键词** 紫外线,臭氧层,气溶胶。

自 70 年代以来全球范围内出现了臭氧层损耗,其主要环境危害是使过多的紫外线 B(UV-B, 280—320nm) 辐射到达地面。UV-B 辐射量的增加将给人类健康,陆生和水生生物带来不良后果<sup>[1-3]</sup>。与此同时,由于矿物燃料的燃烧,火山爆发和森林大火等原因,大气中颗粒物的含量明显高于过去,并且仍然有增加的趋势<sup>[4,5]</sup>。大气层中的气溶胶颗粒物通过对太阳辐射的吸收和散射可以使得地面紫外线 B 显著降低。

有关臭氧层损耗的研究结果都表明,臭氧层损耗必将不同程度地增加全球 UV-B 辐射量<sup>[6-11]</sup>。在这些计算中,气溶胶浓度变化,云顶和局地污染源排放等的影响未予考虑。实际上,这些环境因素对 UV-B 辐射的作用不容低估,特别是气溶胶浓度的增加,可能是导致地面观测到的 UV-B 辐射量呈下降趋势的原因<sup>[5,12]</sup>。本文以北京为代表讨论了臭氧层损耗和气溶胶污染增加对地面 UV-B 辐射变化的影响。

## 1 模式和数据

目前计算太阳紫外辐射量光谱的方法很多,但大多数需求解辐射传输方程,因而显得复杂困难。Green 参数化模式简单,计算误差小于 10%<sup>[4]</sup>。由此,采用此方法计算到达地面的 UV-B 辐射光谱。基本公式如下:

$$D(\theta, \lambda) = \cos\theta \cdot H_{\lambda} \exp(-\sum T_i / \mu_i) \quad (1)$$

$$\mu_i = \left( \frac{\mu^2 + t_i}{1 + t_i} \right)^{\frac{1}{2}} \quad (2)$$

$$S(\theta, \lambda) = \varphi(\lambda, \theta) \cdot M(\lambda, \theta) H_{\lambda} \exp(-\sum T_i) \quad (3)$$

$$\varphi(\lambda, \theta) = S(\lambda, \theta) / S(\lambda, 0^\circ) \quad (4)$$

$$M(\lambda, \theta) = S(\lambda, 0^\circ) / D(\lambda, 0^\circ) \quad (5)$$

$$G(\lambda, \theta) = D(\lambda, \theta) \cdot \cos\theta + S(\lambda, \theta) \quad (6)$$

其中,  $D$  是直接辐射,  $H_{\lambda}$  是大气层外未衰减的太阳辐射强度,  $\theta$  是太阳天顶角,  $\lambda$  是波长,  $T_i$  是空气, 臭氧和气溶胶光学厚度,  $\mu = \cos\theta$ ,  $S$  是散射辐射,  $\varphi$  是  $\theta$  时散射辐射与  $0^\circ$  时散射辐射比率,  $M$  是  $0^\circ$  时散射辐射与直接辐射比率,  $G$  是总辐射。以上各式详细说明见文献[13]。

在此模式中选择参数有臭氧柱厚度, 气溶胶柱厚度, 地面大气压和相对湿度以及地面反射率。臭氧柱厚度, 地面气压和相对湿度采用当地观测站的实际测量结果。气溶胶柱厚度由当地气象站观测的大气能见度推得, 地表反射率选 Green 模式中绿地表面反射率<sup>[4]</sup>。计算中选晴天天气气候而不考虑云层的影响。

## 2 结果和讨论

### 2.1 臭氧层损耗与 UV-B 生物有效辐射剂量变化

评价 UV-B 对某种生物效应的危害大小常用生物有效辐射剂量(DE)表示。生物有效辐射剂量是紫外光谱辐射量与特定生物响应的活跃光谱之乘积。图 1 给出了正常臭氧浓度下,北京地区以 DNA 活跃光谱为权重而表示的 UV-B 生物有效辐射剂量( $DE_{DNA}$ )的月季变化情形。 $DE_{DNA}$ 是各月 15 日的日辐射总量。DNA 活跃光谱是紫外线对产生人体皮肤癌危害效应的响应曲线<sup>[6]</sup>。由图 1 可见,北京地区生物有效辐射剂量 7 月最大,12 月最小。一年中 4 个不同季节,春季(3—5 月)、夏季(6—8 月)、秋季(9—11 月)和冬季(12—2 月)的  $DE_{DNA}$  分别是 15.2, 31.3, 12.6, 和  $2.0mW \cdot m^{-2} \cdot d^{-1}$ 。

当臭氧浓度不同程度减少时,生物有效辐射剂量将不同程度地增加,两者关系可用辐射放大因子(RAF)表示。定义生物有效辐射剂量增加百分率与臭氧总量减少百分率之比为辐射放大因子。图 2 显示了北京地区臭氧总量减少 1%—30% 时,紫外线对 DNA 危害效应的平均 RAF 变化量。RAF 并不是恒定值,而是随着臭氧层损耗的加大而非线性升高。这说明臭氧层损耗越严重,紫外线生物危害效应就越大。当臭氧总量减少 1% 时,  $RAF_{DNA}$  为 2.3, 当臭氧总量减少 30% 时,  $RAF_{DNA}$  增加至 4.2。

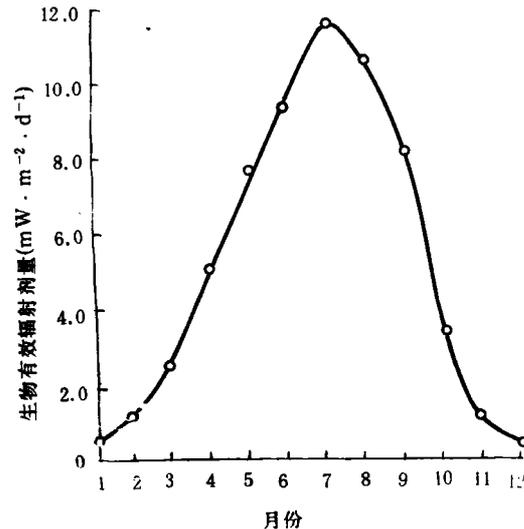


图 1 正常臭氧柱下北京地区  $DE_{DNA}$  月季变化

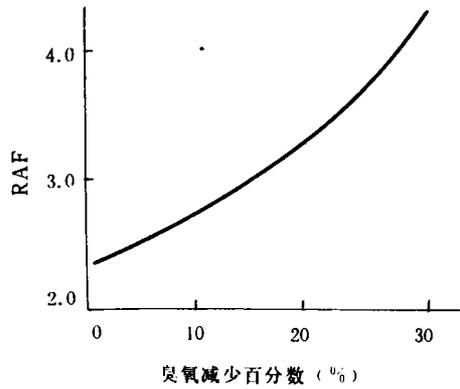


图 2  $RAF_{DNA}$  与臭氧总量变化的关系

假定除气溶胶外其它环境因素不变、通过比较城市和乡村气溶胶浓度下与背景气溶胶水平下的 UV-B 辐射量差异,则可以知道城市和乡村气溶胶污染使 UV-B 辐射降低的程度。由北京地区近 10 年间位于城区和远郊区气象站观测数据得到目前城市和乡村大气能见度分别为 12km 和 32km。由远郊区大气能见度极大值,选背景气溶胶下的大气能见度为 70km。

图 3 表示了大气能见度为 12km 和 32km 时 UV-B 日辐射量与 70km 能见度下 UV-B 日辐射量比率的年均日变化。城区气溶胶污染对 UV-B 辐射的降低量远大于乡村气溶胶污染的作用。城区和乡村气溶胶污染使 UV-B 日辐射量分别降低 45% 和 10% 左右。

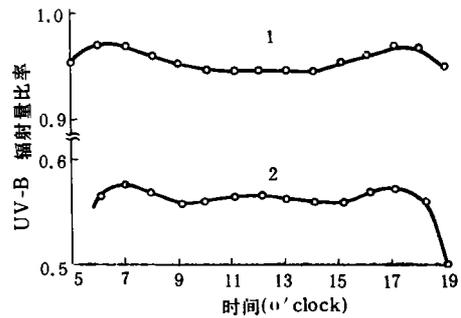


图 3 城市和乡村地区气溶胶污染对 UV-B 辐射的影响

1. 城市 2. 乡村

## 2.2 气溶胶污染对紫外辐射的作用

## 2.3 臭氧层损耗与气溶胶污染对 UV-B 辐射影响的比较

臭氧层损耗和气溶胶污染对到达地面的紫外辐射量的影响作用相反,彼此可以起到部分抵消的效果。图 4 显示了不同程度臭氧层损耗和气溶胶柱厚度增加对 UV-B 辐射量变化的影响大小。图中比率是臭氧柱或气溶胶柱厚度变化后地面 UV-B 日辐射量与正常臭氧和气溶胶时地面 UV-B 辐射量的比值。由图 4 可知,在两者有相同变化率时臭氧层损耗的作用稍大于气溶胶浓度增加所带来的影响。由于全球不同地区臭氧层损耗和气溶胶污染程度不同,地面 UV-B 辐射的变化将不一样。对于北半球人口密集地区,气溶胶污染可能降低臭氧层损耗所产生的危害效果。Scotto 等人对 UV-B 辐射测定结果显示出地面 UV-B 辐射量呈下降趋势正是说明了气溶胶污染对 UV-B 辐射的降低作用<sup>[12]</sup>。对于其它清洁地区,臭氧层损耗对 UV-B 辐射的影响可能大于气溶胶污染的作用。即臭氧层损耗所产生的危害性依然严重。Blumthler 等人<sup>[14]</sup>在阿尔卑斯山区和 Frederick 等人<sup>[15]</sup>在南极洲对 UV-B 观测到增加的趋势说明了这一点。

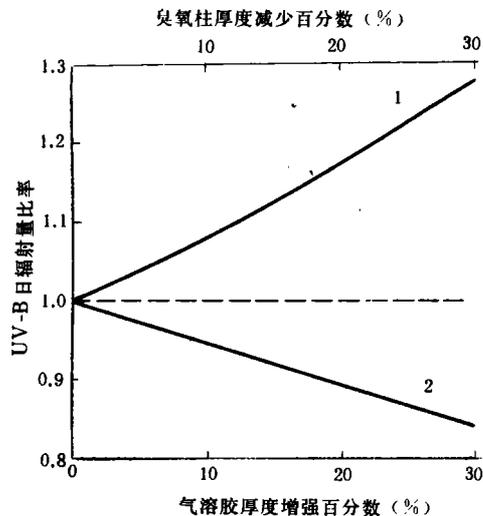


图 4 臭氧层损耗和气溶胶污染变化对 UV-B 辐射量影响的比较  
1. 臭氧 2. 气溶胶

北京地处北半球中纬度区。在过去 10 年间的测定结果显示臭氧总量减少了 5%,与此同时,作为工业发达的城市,气溶胶含量也增加了

3%左右(图 5)。如果只考虑臭氧总量的变化,计算得到地面上以 Robertson-Berger (R-B) 计响应曲线为权重而表示的 UV-B 辐射剂量的变化(图 6),由图 6 可知,UV-B 辐射呈增加趋势,这和臭氧总量的变化情形相反。由线性回归分析得到 1980—1989 年间 UV-B 辐射量年变化率为 1.4%。此结果与 Blumthaler 等人于 1981—1989 年间在阿尔卑斯山(47°N)用 R-B 计测得地面 UV-B 辐射变化趋势 1.1%相近<sup>[14]</sup>。由于阿尔卑斯山处于山区,属于清洁地区,受气溶胶污染的影响很少,所以此结果代表了臭氧层损耗所引起的 UV-B 变化情形。如果将北京地区气溶胶浓度的变化予以考虑,计算得到 10 年间 UV-B 辐射变化见图 6。回归分析显示 UV-B 辐射量年变化率为 -0.7%,这和 Scotto 等人于 1974—1985 年在美国 8 个观测点(30—50°N)用 R-B 计测量得到的 UV-B 变化趋势 -0.7% 相符合<sup>[12]</sup>。由于 Scotto 等人所选的观测点都靠近大城市,气溶胶污染和其它环境因素的影响较大。因此,此结果反映了臭氧总量变化和其它环境因素变化的综合结果。

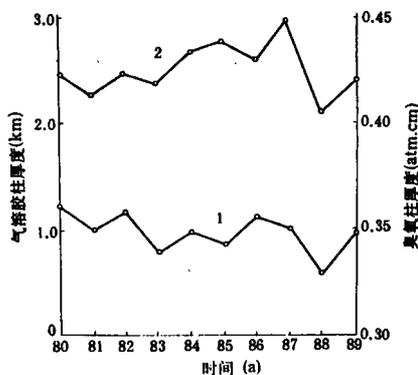


图 5 北京地区 1980—1989 年臭氧柱和气溶胶柱厚度的变化趋势  
1. 臭氧 2. 气溶胶

#### 4 结论

(1) 臭氧层损耗增加了地面紫外辐射量。在北京地区臭氧总量减少 1% 时,地面 UV-B 辐射对 DNA 危害效应的辐射放大因子为 2.3,臭氧总量减少的程度增加时,  $RAF_{DNA}$  则非线性增加,

当臭氧总量减少 30% 时,  $RAF_{DNA}$  增加为 4.2。

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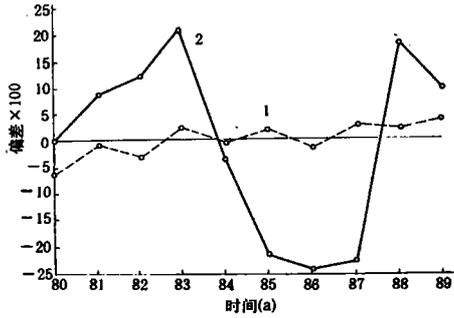


图 6 北京地面 1980—1989 年间臭氧和气溶胶柱厚度变化后地面 UV-B 辐射的相应变化趋势

1. 臭氧 2. 臭氧和气溶胶

(2) 计算结果说明, 城区和乡村不同气溶胶污染分别使 UV-B 辐射降低 45% 和 10% 左右。

(3) 北京地区在 1980—1989 年间, 大气臭氧总量减少了 5%, 气溶胶柱厚度增加了 3%, 仅由臭氧总量变化而引起的地面 UV-B 辐射量年变化率为 1.4%, 当考虑气溶胶柱厚度变化时, UV-B 辐射量的年变化率则是一 0.7%。这和相近纬度地区测定的 UV-B 辐射年变化趋势相似。

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(上接第 32 页)的 DO 水平。运用内源反硝化脱氮。保持进水适宜的 C/N 以避免过剩的 C 转化为细胞贮藏 C。在采用上述措施后, 反硝化系统的运行成本可望得到降低。

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## Abstracts

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terms of the ratio of the concentration of dissolved ion (mg/L) to the activated sludge (kg VS/L).

**Key words:** anaerobic system, heavy metal, zinc.

**Analysis and Prediction on the Traffic Noises from an Elevated Express Compound Highway.** Chen Ziming, Lu Deming et al. (Dept. of Physics, Qingdao University of Oceanography, Qingdao 266003); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 24—28

Based on a section of the Jinan-Qingdao Express Highway in the suburbs of Qingdao City which is a typical compound highway of elevated structure, an analysis has been made on the relationship between its traffic noises and the factors involved. A mathematical model has been also established for predicting the traffic noises from an elevated express compound highway. It is found that the theoretical calculations based on this model are generally coincident with the actually simulated measurements.

**Key words:** elevated express compound highway, insonified zone, peak volume hour, running noise of a single vehicle.

**Influence of Different Carbon Sources on Denitrification.** Xu Yatong. (Dept. of Environmental Science, East China Normal University, Shanghai 200062); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 29—32

In a suspended sludge system, the rates of denitrification and carbon uptake can follow a zero-order reaction when the carbon supply was from an unlimited, single kind of carbon source at a suitable pH and temperature. It was found that a mixed volatile fatty acid (VFA) C-source resulted in a higher rate of denitrification than any of the individual VFA C-sources which formed the mixed one. Of the VFAs, acetate gave the highest rate of denitrification. The VFAs gave a higher rate of denitrification than their corresponding alcohols. The means of reducing the carbon consumption and the cost of treatment in a denitrification system had been also discussed.

**Key words:** biological denitrification, suspended sludge, carbon source, rate of denitrification, C-uptake rate.

**Simulation of Thermal Structure and Evaporation for Lakes.** Congzhi Zhou et al. (Teaching and Research Section for Water & Heating Logistic Engineering University, Chongqing 630041); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 33—37

An one-dimensional eddy diffusion model was used

for prediction of the annual vertical temperature profile and evaporation rate of a lake. The governing equation was a non-linear heat transfer equation assuming horizontal homogeneity. No lake-specific fitting of the parameters of the model was necessary. Eddy diffusivities were computed with Richardson Number. The heat exchange at the water surface was formulated by the energy balance approach, and the bottom of the lake was considered to be insulated. The governing equation was solved by finite difference. Computation was made for Lakes Colorado City and Calhoun. Quantitative and qualitative agreement between computed and measured temperature profiles was very good, with an error of less than 2°C. The computed annual evaporation capacity approached the one measured and the difference between them was only 5% of the measurement value.

**Key words:** lake, thermal structure, evaporation.

**Promoting the Electrolysis Efficiency of a Bipolar Electrolyser by Adding a Coated Activated Carbon.** Zhou Kanghan, Zhou Ding. (Harbin Institute of Technology, Harbin 150006); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 38—40

It has been found that improving the conditions of contact between particles in a bipolar electrolyser is a key to promoting its electrolysis efficiency. Such an improvement has been achieved by adding a coated activated carbon to the electrolyser and the satisfactory results were obtained. With a Proper formulation, the addition of a coated activated carbon at a ratio of 100 : 30 allowed the electrolysis efficiency to increase from 130% to 245% and a stable, uniform distribution could be kept during an operation for about 300h.

**Key words:** electrolysis efficiency, bipolar electrolyser, coated activated carbon.

**Ozone Layer Depletion, Aerosol Pollution and Solar UV-B Radiation at the Ground.** Wang Shaobin (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 41—44

Ozone layer depletion and aerosol pollution have an influence on the solar ultraviolet radiation reaching the ground. A computation indicates that the radiation amplification factor (RAF) for a DNA damage varies from 2.3 to 4.2 when a reduction in column ozone goes from 1% to 30%. Since the industrial revolution, the daily UV-B radiation in urban and rural areas has decreased by about 45% and 10%, respectively, that can be attributed to aerosol pollution. The computed UV-B radiation due to the ozone reduction in Beijing shows an increasing

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trend at an average annual rate of 1.4% during the period of from 1980 to 1989. By taking the variations in atmospheric aerosol concentration into account, the computed UV-B radiation shows a trend of negative shift at an annual rate of 0.7%. These variations in UV-B radiation are found to be close to those measured in the Alpine regions (47°N) and the United States (30—50°N).

**Key words:** UV-B radiation, ozone layer, aerosol pollution.

**Method for Treating the Exhaust Gases from a Methanol Fueled Internal Combustion Engine; (I) Deep Oxidation of CH<sub>3</sub>OH over Basic Metal Oxides and Precious Metal Catalysts.** Wang Jin'an and Wang Ren (Institute of Industrial Catalysis, East China University of Science and Technology, Shanghai 200237); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 45—48

It was found that the deep oxidation of CH<sub>3</sub>OH over all the different catalysts studied produced both HCHO and HCOOCH<sub>3</sub>. Among the basic metal oxide catalysts, CuO/r-Al<sub>2</sub>O<sub>3</sub> exhibited the best activity with an optimum loading of about 10%—20%. The catalyst CuO/r-Al<sub>2</sub>O<sub>3</sub> prepared with the method of homogeneous coprecipitation had a better activity than others. Among the precious metal catalysts studied, Ag/r-Al<sub>2</sub>O<sub>3</sub> was the best one and had T<sub>50</sub> = 135°C and T<sub>95</sub> = 190°C for the oxidation of CH<sub>3</sub>OH. The different catalysts had a "volcano" type of curve relationship between their activities and  $\Delta H_f^0$ .

**Key words:** methanol, formaldehyde, deep oxidation, catalyst.

**Study on the Factors Affecting the Content of Heavy Metals in Lettuce (*Lactuca sativa var. longifolia*) Growing on Mixed Sludge Medium.** Liao Zhongwen, Wang Weihong et al. (Dept. of Soil Science, South China University of Agriculture, Guangzhou 510642); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 49—52

A lettuce growing medium pot experiment was conducted to study the effects of the rate of sludge application, the volume of medium and harvest time on the contents of heavy metals Zn and Ni in Lettuce. It was found that the relationship between the rate of sludge application and the content of heavy metals varied with the growing medium. Under the condition of a small volume of medium, a higher rate of sludge applied led to a lower content of heavy metal but a higher yield of Lettuce. The heavy metal had a content in Lettuce depending on

the harvest time. The causes for leading to the above results and their implication for the production of Lettuce were also discussed.

**Key words:** sludge, Zn, Ni, medium culture, *Lactuca sativa var. longifolia*.

**Study on the Rehabilitation of an Artificial Ecosystem of Vegetation on a Waste Landfill Site.** Dun Wanru, Yue Xilian et al. (Qingdao Institute of Environmental Protection, Qingdao 266003); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 53—58

An artificial ecosystem of vegetation was rehabilitated with 16 species of xylophyta and 9 species of herbaceous herb by using three different techniques of cultivation on a waste landfill site. The results showed that methane given out of the landfill site was a main factor affecting the rate of vegetation survival. On a landfill site where the refuses have been dumped for 1 to 2 years, the desired results were obtained for planting the vegetation of a shorter growing period. The species of xylophyta having a longer period of growth were not suitable to be planted on a discarded refuse landfill site of 1 year and could be planted on a 2 year discarded refuse landfill site only by covering an earth layer of 60 cm thick to break methane given out. The species of plant which have a higher tolerance have been screened as follows: *Lycium chinensis* Mill., *Melia azeclarach* L., *Anorpha fruticosa* Linn., *Robinia pseudoacacia* Linn., *Fraxinus chinensis* Roxb., *Ligustrum lucidum* Ait., *Medicago sativa* L., *Eragrostis pilosa*, *Eleusine indica*, *Eragrostis ferruginea* Beauv.

**Key words:** sanitary landfill, abandoned land, methane gas, vegetation.

**Study on the Catalytically Hydrogenated Conversion of Carbon Dioxide.** Lu Zhenju, Lin Peizi et al. (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023); *Chin. J. Environ. Sci.*, 15(2), 1994, pp. 59—61

A method was described for the catalytically hydrogenated conversion of carbon dioxide to chemical products. Under the different conditions of reaction, an iron catalyst (Fe/AC) had been excellently characterized by the conversion of carbon dioxide to light olefins, liquid hydrocarbons, and liquefied petroleum gas. A Cu-Zn-Y zeolite catalyst exhibited a good selectivity for converting carbon dioxide to DME. Carbon dioxide was converted to alcohols over a Rh-V catalyst.

**Key words:** carbon dioxide, catalytic hydrogenation, catalyst, chemical products, reaction.