

Special topic

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Efforts to improve Japanese women's status in STEM fields

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Abstract: I discovered novel copper and silver carbonyl catalysts while at the National Institute of Advanced Industrial Science and Technology. The energy saving synthesis of *tert*-carboxylic acids was developed using the carbonylation reaction of olefins or alcohols using these novel copper or silver carbonyl catalysts under atmospheric pressure and at room temperature. After retiring from the institute, I was involved in efforts to improve women's status in natural science, technology, engineering, and mathematics. I worked for the gender equality committee of the Chemical Society of Japan and the Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering, which sent recommendations to the government on how to realize a society with gender equality. The government accepted our recommendations, and the numerical target for female researchers was written into the 3rd Science and Technology Basic Plan in 2006. Based on the plan, the Ministry of Education, Culture, Sports, Science and Technology started programs to aid universities in increasing the percentage of female researchers from 2006.

Keywords: carbonylation; copper carbonyl catalyst; Distinguished Women in Chemistry and Chemical Engineering; EPMEWSE; gender equality; MEXT; STEM; *tert*-carboxylic acid.

Introduction

Japan made remarkable progress in the development of science and technology after the Second World War. However, the participation of women in Japanese society lags behind other nations. At present, Japan's Gender Gap Index is 114th among 144 countries (the World Economic Forum's Global Gender Gap Report 2017). In particular, the ratio of female professionals trained in science, technology, engineering, and mathematics (STEM) fields is far behind other developed countries. Why has Japan been so slow in maximizing the potential of female scientists in STEM fields? Survey results have indicated that there are too few women in positions of authority who can help younger women with career enhancement. Furthermore, male scientists show an unconscious bias when evaluating their female colleagues. Finally, female scientists often avoid competition and underestimate their abilities, leading to passivity when seeking leadership roles [1–3]. Additionally, many women with children have great difficulties in balancing their research and child-rearing responsibilities, because in Japan male participation in housework is very low compared to other countries [4].

In Japan, the government has implemented various measures to address the traditionally male-dominated culture, starting with the enactment of the Gender Equality in Employment Act in 1985. However, progress has been slow [5]. In the science field, Dr. Katsuko Saruhashi, a Japanese geochemist, established the Saruhashi Prize to encourage outstanding young female scientists in STEM fields in 1980. Thirty-seven female researchers have received the Saruhashi Prize, and they are working to encourage younger female scientists.

I was engaged in research at the National Institute of Advanced Industrial Science and Technology in 1965. I discovered novel copper and silver carbonyl catalysts. The energy-saving synthesis of *tert*-carboxylic

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acids then became possible through the carbonylation reaction of olefins or alcohols using these novel copper or silver carbonyl catalysts under atmospheric pressure and at room temperature. This research was evaluated highly by academic societies and the government, and I received more than 10 awards [6–10]. However, my promotion to director of the department was not realized, because in Japan a strong unconscious bias against women was present, especially in the STEM fields.

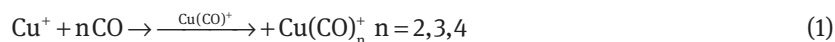
After my retirement from the institute, I was involved in efforts to improve women's status in STEM fields. In order to increase the number of female researchers and improve their working environment, we established the Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering (EPMEWSE) in 2002. The EPMEWSE conducted a comprehensive survey of approximately 20 000 members of 67 academic societies to determine the difficulties faced by female scientists. It then sent recommendations to the government on how to realize a society with gender equality. The contents of the recommendations were included in the 3rd Science and Technology Basic Plan in 2006, and the target proportion for hiring female scientists was set at 25 % (20 % in science, 15 % in technology, and 30 % in agriculture). Based on the plan, in 2006, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) began epoch-making programs designed to improve women's working conditions and increase the number of female scientists.

Many female Japanese scientists are making tremendous efforts to carry out original research studies, and at the same time, to improve women's working conditions. Against this background, the establishment of the Distinguished Women in Chemistry/Chemical Engineering 2011 International Year of Chemistry Project was very encouraging not only for female chemists, but also for all members of STEM fields and government personnel.

In this paper, I would like to introduce not only my research, but also the many efforts being made to improve working conditions for women in STEM fields.

Carbonylation of olefins or alcohols using novel copper or silver carbonyl catalysts

As mentioned, I discovered a novel copper and silver carbonyl complex during an analysis of carbon monoxide. The energy-saving synthesis of *tert*-carboxylic acids through the carbonylation reaction of olefins or alcohols by using the copper or silver carbonyl catalyst in strong acids then became possible [6–10]. By using the copper or silver carbonyl catalyst, the reaction condition to produce *tert*-carboxylic acids was improved from high pressure and high temperature to atmospheric pressure and room temperature. Furthermore, the purity of the products was improved. Among copper carbonyl complexes, $\text{Cu}(\text{CO})_n^+$ had catalytic activity; however, $\text{Cu}(\text{CO})^+$ did not have any catalytic activity. Although the Cu^+ ion is easily oxidized and inactivated, the Ag^+ ion is stable to oxygen. Therefore, $\text{Ag}(\text{CO})_2^+$ is used, even in the presence of air. As these catalysts have a positive charge, they were called a cationic metal carbonyl complex.



Later, the discovery of the cationic metal carbonyl complex was expanded to Au, Pd, Pt, Co, Rh, and Ir, and similar catalytic activities were observed [11–15]. My coresearchers were delighted to discover new cationic metal carbonyl complexes and applications as catalysts.

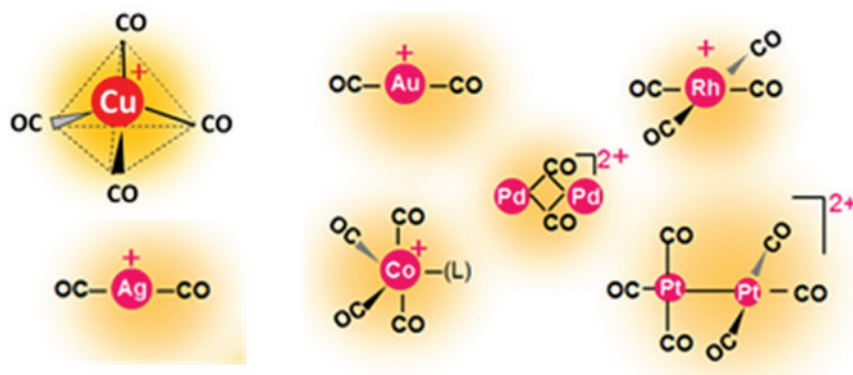


Fig. 1: Representative cationic metal carbonyl cations.

The characteristic points of cationic metal carbonyl complexes are the positive charge of metal, and the formation of an M–C bond by a mainly σ -dative bond from CO to metal. Therefore, ν_{co} is observed at higher wave number than free CO (2143 cm^{-1}).



As the M–C bond is unstable, CO can easily react with olefins under atmospheric pressure and room temperature. The representative cationic metal carbonyls are shown in Fig. 1.

The industrial applications of *tert*-carboxylic acids included painting cars and ships [16].

Reuse of carbon dioxide to mitigate the greenhouse effect

The greenhouse effect gives us a serious problem such as unusual weather and natural disasters. Carbon dioxide is one of the main causes of the greenhouse effect. We tried to convert carbon dioxide into hydrocarbons or methanol by reacting hydrogen using catalysts such as CuO/ZnO/Zeolite or CuO/ZnO/FeO/Zeolite [17–19]. This was a big national project – my first experience of such. The director of the research institute recognized me as a lead researcher, and I was able to have many co-researchers. As the production of hydrogen is developing, this method will be used to resolve the greenhouse effect in the future. In 1991, I attended the Nobel Symposium to discuss the reduction of carbon dioxide, and I also attended the Nobel ceremony.



Unconscious bias

These original studies were evaluated highly by academic societies and the government, and I received many awards such as the Saruhashi Prize (1986); the Synthetic Organic Chemistry Award, Japan (1989); the Award from the Director General of the Science and Technology Agency, Japan (2000); the Catalysis Society of Japan Award for 2001 (2001); the Chemical Society of Japan Award for Creative Work for 2002 (2002); the Distinguished Women in Chemistry/Chemical Engineering 2011 International Year of Chemistry Project (2011); and seven more. However, my promotion to director of the department was not realized because of a strong unconscious bias against women in Japanese society. Men who have had similar achievements are usually promoted to director of the department or the head of a research institute.

Foundation of the gender equality committee of the Chemical Society of Japan

The number of female members of the Chemical Society of Japan (CSJ) was 3150 (12 %) and that of students 1185 (20 %) in 2017. The number of women is gradually increasing. In 2018, professor Maki Kawai, director of the Institute for Molecular Science and recipient of the IUPAC 2015 Distinguished Women in Chemistry or Chemical Engineering award, was elected as the first female president in the 140 year history of the CSJ. The number of women on the board of directors is 1 out of 26 in 2018, and there have only 10 been female board members in total during its 140 years. The total number of male board members was more than 2000 in that period. I was the second member of the board of directors in 2001~2002, and the first chairperson of the Gender Equality Committee (GEC) of the CSJ.

The GEC of the CSJ was established in 2002. The committee aims to create a real gender equivalent society in the fields of chemical science and engineering. The realization of a research environment where men and women can play significant roles by displaying their individuality is desired. In 2003, the following positive actions as part of three agendas were approved: (1) Increasing female members to 20 % of the board of directors, branches, sectional meetings, and various committees; (2) including female scientists in plenary lectures or invited lectures as role models; and (3) establishing awards for outstanding young female chemists.

The CSJ Award for Outstanding Young Women Chemists under 40 years old was established in 2012. Two outstanding female chemists receive the award at each annual meeting of the CSJ, with 12 total recipients so far. Young female chemists must make significant efforts to develop original research and their family lives (childbirth and child care) in their twenties to forties.

The GEC of the CSJ has organized an international female chemist symposium at Pacificchem in Hawaii since 2005 with members of the American Chemical Society, Canadian Society for Chemistry, Korean Chemical Society, and the Royal Australian Chemical Institute. We are very encouraged by the groundbreaking activities of the US.

Foundation of EPMEWSE

Japan is well qualified to promote scientific advancement. However, the proportion of female professionals in science – including the humanities, social science, and natural science – was only 15.7 % in 2017, which is far behind other developed countries (Fig. 2). The low female ratio is especially noticeable in STEM fields. In order to overcome this gender gap in Japan, we established EPMEWSE in 2002. The CSJ discussed the establishment of EPMEWSE with other academic societies like the Japan Society of Applied Physics and the Physical Society of Japan. At present, EPMEWSE includes 104 academic societies in STEM fields, all actively working toward gender equality in Japan (<http://www.djrenrakukai.org/>). EPMEWSE promotes activities related to gender equality all over Japan.

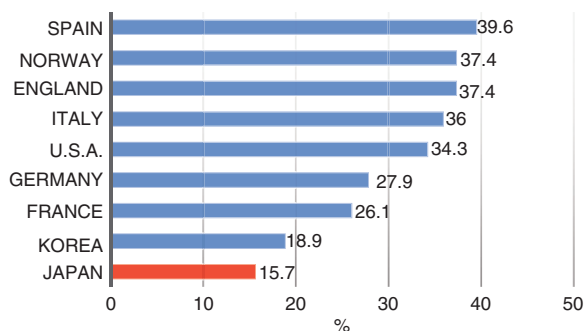


Fig. 2: Proportion of female researchers in OECD countries (The Cabinet Office, Gender Equality Bureau, 2017).

The 104 societies have different characteristics. The proportion of women is 15–25 % in the life sciences group (which includes the Molecular Biology Society of Japan and the Japan Biological Society), 5–15 % in the classical society (which includes the CSJ and the Physical Society of Japan), and less than 5 % in the engineering group (which includes the Japan Society of Mechanical Engineering and the Japan Society of Civil Engineers). Each society acts as secretary for 1 year and organizes the symposium or sends recommendations. There are many working groups that focus on matters such as the analysis of questionnaires or the preparation of recommendations.

The main activities include investigating female researchers by sending out a questionnaire to members every 5 years and sending recommendations to the government every year on how to improve women's position. The first recommendation in 2005 included the following five agendas: (1) To start model research projects in STEM fields and prioritize the allocation of funds; (2) to set a target number for hiring and promoting female scientists; (3) to establish a gender equality office and coordinator; (4) to promote measures for balancing research and childrearing; and (5) to fund an invitation program to STEM fields for female high school students. The Japan Science Council and other academic societies sent various recommendations to the government. Most of the recommendations were then accepted and incorporated into the 3rd Science and Technology Basic Plan in 2006. Advanced recommendations have been sent to the government every year in order to ensure continuous funding support. The following two subjects were recently emphasized: (6) Training female leaders and (7) appointing female managers [20–25].

Questionnaire surveys have been sent out four times since 2003. Japanese women have a tendency to hesitate in taking leadership roles in research groups. However, the number of women who want to be leaders is gradually increasing. According to Ohtsubo's analysis, women who want to be research leaders at universities constituted 17 % in 2003; however, this increased to 22 % in 2007, 24 % in 2012, and 29 % in 2017 [26]. It is important to encourage women to escape their tendency to underestimate themselves.

EPMEWSE influences not only the government, but other science fields as well. The Gender Equality Association for Humanities and Social Science was established in the field of humanities and social science in 2017.

Policies of the Japanese government

The Japanese government regards the realization of a society with gender equality as the essential issue of the twenty-first century. The government provided the Basic Act for a Gender-Equal Society in 1999, devised the Gender Equality Basic Plan in 2000, then established the Gender Equality Bureau in the Cabinet Office in 2001. In 2003, the headquarters for the promotion of Gender Equality (Cabinet Office) set the goal of realizing a ratio of 30 % females in leadership positions in society by 2020 [27]. This is an ambitious target.

The Japanese government recognized the importance of increasing the participation of women in STEM fields after requests from EPMEWSE and other scientific groups. Policies to support female researchers in STEM fields were then included in the 3rd Science and Technology Policy in 2006, and the numerical target for hiring female scientists was set at 25 % (20 % in science, 15 % in technology, 30 % in agriculture, and 30 % in health). This target was a monumental landmark. Five years later, the target was increased to 30 %.

Based on the basic plans, in 2006, MEXT started support programs for female researchers in STEM fields, as follows:

1. Support in returning to science from childcare leave.
2. Support programs for female researchers (improving work environments and increasing the number of female researchers).
3. Introducing STEM courses to female high school students.

The purpose of program 2 was to establish a new system to balance research and childrearing for female researchers in order to maximize their abilities. According to Ohtsubo's report, the model for the Japanese

policy was the US ADVANCE program [20–25], but the support of the Japanese government lagged behind the US by about 30 years. Now, 12 years have passed since MEXT started the program, and more than 100 universities and research institutes have joined. The support systems have since been expanded to the humanities, social sciences, and companies.

The Act on Promotion of Women's Participation and Advancement in the Workplace went into effect on April 1, 2016. This act aims to promote the participation and advancement of women in the labor force. Government agencies and private sector corporations with more than 300 employees will be required to collect and analyze data on issues of gender and employment, such as the rate of newly hired female employees, the gender gap in years of continuous employment, work hours, and the ratio of female managers. They are also required to devise and disclose action plans on improving gender equality, and provide data regarding women's participation and advancement.

Support programs for female researchers in STEM fields

In 2006, many universities and government research institutes started model programs to help female researchers balance research and childcare, and in 2009, they accelerated programs to increase the appointment of female faculty members. More than 100 universities and government research institutes have joined these programs and accepted the challenge of improving their working conditions.

Various efforts have been carried out to improve working conditions, as follows: (a) A call to increase the appointment of female researchers up to 30 %; (b) the provision of academic assistants to female researchers with children; (c) symposiums to encourage female researchers; (d) seminars for executive members on changing their way of thinking; (e) support in submitting English papers or attending international symposiums; (f) support in gaining research funds; (g) training of female leaders and promotions to higher positions; and (h) the publication of newsletters, booklets, etc.

The effect of the provision of academic assistants was significant, and the number of academic papers and research funds increased 3.7 and 3.2 times, respectively [8]. Promotions to higher positions began to be realized, and female vice-presidents appeared. The number of female researchers and awards recipients increased. The effects of these support programs were obvious.

An example of the appointment of female faculty members at Kobe University is shown in Fig. 3. The number of female faculty members in STEM fields was 21 in 2009, and there was no tendency to accept women before then. However, the introduction of an incentive for researchers with a term of 5 years for divisions that appointed women made possible the appointment of female members. The intentional appointment of female faculty members began in 2010 as part of a 5 year plan for doubling their number. As the newly appointed female members were excellent, unexpected appointments of female faculty members took place. The number of female faculty members then became 44, and it more than doubled in 2014.

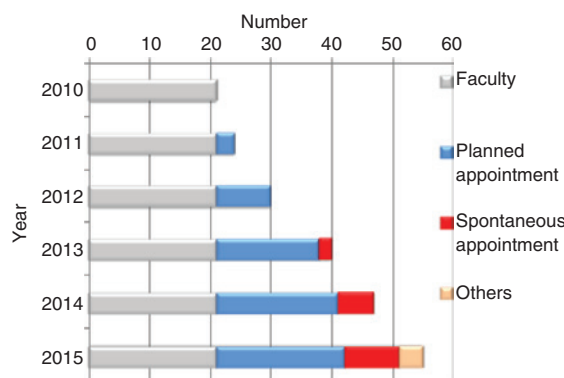


Fig. 3: Appointments of female faculty members in STEM fields at Kobe University.

Inviting female high school students into STEM fields

In 2014, although the percentage of female students enrolled in universities (including colleges) was almost 55 %, that of STEM fields was still low at 19 %. In 2006, the Japanese government started a program to invite girls to join STEM fields. Female high school students are influenced by the unconscious biases of parents and teachers, who often believe that STEM fields are not suitable for girls or women. In the Kansai area, volunteer groups from Kyoto University, Osaka University, Kobe University, Nara Women's University, Osaka Prefecture University, and Osaka Municipal University established the Kansai Kagakujuku in order to invite female high school students to STEM fields. Female high school students can enjoy conducting many kinds of experiment several times a year and those with an interest in science can enter a STEM field at university (Fig. 4). The program has been successful and the graduates of Kansai Kagakujuku have now joined the program as teaching assistants, inviting female high school students to STEM fields. In 2018, after 12 years of experience, a new consortium was started as a non-profit organization to secure management and independence.



Fig. 4: Female high school students enjoying experiments as part of Kansai Kagakujuku (2009).

Introducing science to elementary school children

It is important to awaken the interests of science from childhood. Most school children have a natural interest in science, but these interests decrease as the children age. Furthermore, the number of students who study in STEM fields has recently been decreasing.

At its national meeting every year, the CSJ in Tokyo or Osaka offers invitation programs for science to elementary school children. It is more effective to encourage an interest in science through experiments. There are many volunteer activities to convey the appeal of science to elementary school children. In Ibaraki city, an experimental science course has been organized for elementary school children since 1992. An intensive and advanced experimental course for children started 2018, and I am involved as an instructor.

Furthermore, elementary and junior high school children conduct independent research during their summer vacations. The board of education has collected studies from each school in Ibaraki city and selected 12 excellent projects since 2014. Twelve elementary and junior high school students are bestowed a science



Fig. 5: The 3rd Ibaraki city Souma Yoshie Science Award (2016).

award from Ibaraki city in November (Fig. 5). The best one receives the Souma Yoshie Science Award from Ibaraki city. There are no differences between boys and girls in their studies. I eagerly wish for this tendency to be realized in professional fields in the near future.

Conclusion

Twelve years has passed since the support program for female researchers began. However, universities that are carrying out this program constitute only 12 % of all Japanese universities, so it will take time until this program spreads all over Japan. I eagerly anticipate the percentage of female researchers exceeding 30 % soon, and hope that it will reach 50 % in the future. The realization of a research environment where men and women can play significant roles by displaying their individuality is strongly desired.

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Article note: A special collection of invited papers by recipients of the IUPAC Distinguished Women in Chemistry and Chemical Engineering Awards.

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