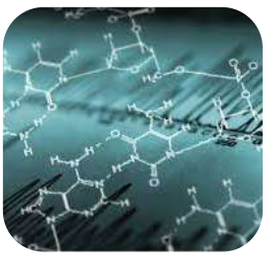

# Berita IKM - Chemistry *in* Malaysia

## June 2022


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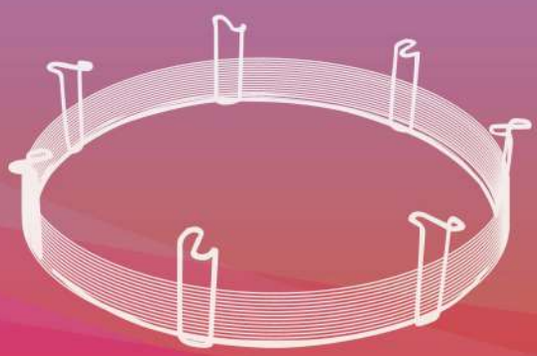

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# Message from the President

**Year 2022 – IKM Going Full Steam Ahead**

I believe that we have entered the endemic stage of COVID-19. For the last 3 months, the number of cases has been hovering around one to two thousands. And with very small number of deaths, we have entered a stage that it has become endemic.

What does this mean for IKM? We are going full steam ahead. We have a good start for 2022. We just completed the 10th Symposium on Best Practices and Innovations in Laboratory Management (10BPI-Lab) recently followed by the Malaysian National Chemistry Convention (MNCC) comprising a Forum on Chemistry & Climate Change (C&CC) and the 55th Annual General Meeting (55AGM). For the Forum, we have a report in this issue of Berita IKM.

The next major event will be **Kuiz Kimia Kebangsaan Malaysia**, or **$K_3M$**, **2022** which will take place on 29th September 2022 in all schools taking part in the Quiz. This year we are expecting more than 30,000 students taking part. We are also celebrating 21 years of $K_3M$ from 2002 – 2022 with the theme – ***Celebrating 21 years of excellence in chemistry education in Malaysia***.

Another significant event is the **International Congress on Pure & Applied Chemistry (ICPAC) 2022** which will be held from 22nd – 27th November 2022 at the Magellan Sutera Resort, Kota Kinabalu, Sabah. **ICPAC KK 2022** will be a hybrid conference and we have very good response from the Japanese participants. So far 341 Japanese scientists have indicated they will participate and another 100 – 150 will be coming. This will be the biggest ICPAC that we will organise since 2016.

After ICPAC KK 2022, we shall have **Malam Kimia 2022** on 2nd December 2022 at the One World Hotel, Petaling Jaya.

We have also just completed the **Programme Standards for Chemistry** to be submitted to the Malaysian Qualification Agency (MQA) to be implemented as the Standard Chemistry Curriculum for Chemistry Programmes in universities in Malaysia.

So we are moving full steam ahead for 2022 and we shall have even more programmes and activities in the year 2023 and beyond.

So, we have won our battle against COVID-19 but we must stay vigilant and strong to win the wars against any future pandemic.

Best wishes.

**Datuk ChM Dr Soon Ting Kueh**
President, Institut Kimia Malaysia
Date: 30th June 2022

Polymer Chemistry

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# Reconsidering terms for mechanisms of polymer growth: the "step-growth" and "chain-growth" dilemma

Chin Han Chan, [a] Jiun-Tai Chen,[b] Wesley S. Farrell, [c] Christopher M. Fellows,[d,e] Daniel J. Keddie, [f] Christine K. Luscombe, [g] John B. Matson, *[h] Jan Merna,[i] Graeme Moad, [j] Gregory T. Russell, [k] Patrick Théato, *[l] Paul D. Topham [m] and Lydia Sosa Vargas [n]

The terms "step-growth polymerization" and "chain-growth polymerization" are used widely in both written and oral communications to describe the two main mechanisms of polymer growth. As members of the Subcommittee on Polymer Terminology (SPT) in the Polymer Division of the International Union of Pure and Applied Chemistry (IUPAC), we are concerned that these terms are confusing because they do not describe the fundamental differences in the growth of polymers by these methods. For example, both polymerization methods are comprised of a series of steps, and both produce polymer chains. In an effort to recommend comprehensive terms, a 1994 IUPAC Recommendation from the then version of SPT suggested *polycondensation* and *polyaddition* as terms for the two variants of "step-growth polymerization", and similarly *chain polymerization* and *condensative chain polymerization* for the two variants of "chain-growth polymerization". However, these terms also have shortcomings. Adding to the confusion, we have identified a wide variety of other terms that are used in textbooks for describing these basic methods of synthesizing polymers from monomers. Beyond these issues with "step-growth" and "chain-growth", synthesis of polymers one monomer unit at a time presents a related dilemma in that this synthetic strategy is wholly encompassed by neither of the traditional growth mechanisms. One component of the mission of IUPAC is to develop tools for the clear communication of chemical knowledge around the world, of which recommending definitions for terms is an important element. Here we do not endorse specific terms or recommend new ones; instead, we aim to convey our concerns with the basic terms typically used for classifying methods of polymer synthesis, and in this context we welcome dialogue from the broader polymer community in a bid to resolve these issues.

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## Introduction

Nearly all polymers that are chemically synthesized from monomers can be grouped into two classes based on their mechanism of polymer growth. The terms "step-growth" and "chain-growth" are currently used widely by the polymer chemistry community to classify these mechanisms of polymer growth.[1] In brief, "step-growth" typically refers to polymers that are synthesized from one (or more) type(s) of multifunctional monomer(s) where at least bifunctionality is required,

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with growth occurring between monomers, oligomers, or polymers of any length. An example is the synthesis of linear polyamides from diamines and dicarboxylic acids. "Chain-growth" generally describes polymers that increase in molar mass by a chain reaction process of monomers adding to polymeric active sites; active sites are typically created through inclusion of an external initiator in the polymerization reaction. An example is the synthesis of polystyrene from styrene and a radical initiator. The potential confusion created from these traditional terms is immediately apparent: both growth mechanisms require a series of (elementary) steps, and both produce polymer chains. Also, it is a tautology to say "-growth polymerization" because there cannot be polymerization without growth. Fig. 1 shows these two mechanisms of growth graphically for the synthesis of linear polymers, highlighting elements of our concerns with the terms "step-growth" and "chain-growth".

Recommending consistent and logical terminology to the global chemistry community is one goal of the International Union of Pure and Applied Chemistry (IUPAC). The IUPAC Subcommittee on Polymer Terminology (SPT), a body that dates back to 1952 in one form or another (referred to here as SPT, even when we technically mean an earlier version of this subcommittee with a different name),[2] seeks to provide guidance and recommendations on issues of terminology and nomenclature related to polymers. This goal is carried out mostly through publications recommending definitions of terms and systems of nomenclature that can be applied and understood globally.

As current members of and contributors to SPT, in this discussion we seek to notify the community of our concerns with terms used to describe mechanisms of polymer growth in the scientific literature and in textbooks. A messy situation currently exists where a wide variety of terminology is used, which is obviously undesirable for such a fundamental matter. Common terms include "step-growth" and "chain-growth", but also many others detailed below, including some terms proposed by this subcommittee that fail to meet our standard of clear and self-consistent terminology.

A 1974 document from this subcommittee defined the terms "addition polymerization" (polymerization by a repeated addition process) and "condensation polymerization" (polymerization by a repeated condensation process).[3] In a 1994 Recommendations document from SPT, it was recognized that "addition polymerization" and "condensation polymerization" only distinguish between polymerizations in which a small-molecule by-product (a condensate) is produced and those where one is not.[4] In other words, these terms do not identify a mechanism of polymer growth. Thus, the terms *polyaddition* and *polycondensation* were recommended for *polymerizations in which the growth of polymer chains proceeds by addition reactions or condensation reactions between molecules of all degrees of polymerization* (*i.e.*, "step-growth"), usually in a non-chain reaction. The terms *chain polymerization* and *condensative chain polymerization* were recommended as terms for polymers made in a reaction where monomers react only with active polymer chains *via* a chain reaction pathway (*i.e.*, "chain-growth"). This is summarized in Fig. 2, reproduced from the 1994 document, which deprecated use of the terms "chain-growth" and "step-growth".

While the four terms suggested in 1994 are more comprehensive and without doubt superior to preceding terminology, there have been four issues with these terms from the outset:

(1) The terms *polycondensation* and *polyaddition* sound very similar to the historical terms "condensation polymerization" and "addition polymerization", proposed by Carothers nearly a century ago.[5] Carothers' terms represented the first attempt at terminology in the present context, and these terms are still widely used today (see below), even though their shortcomings became evident almost immediately; for example, polyurethanes, first made in 1937 in a "step-growth" manner,[6] involve no condensate in their preparation. This similarity

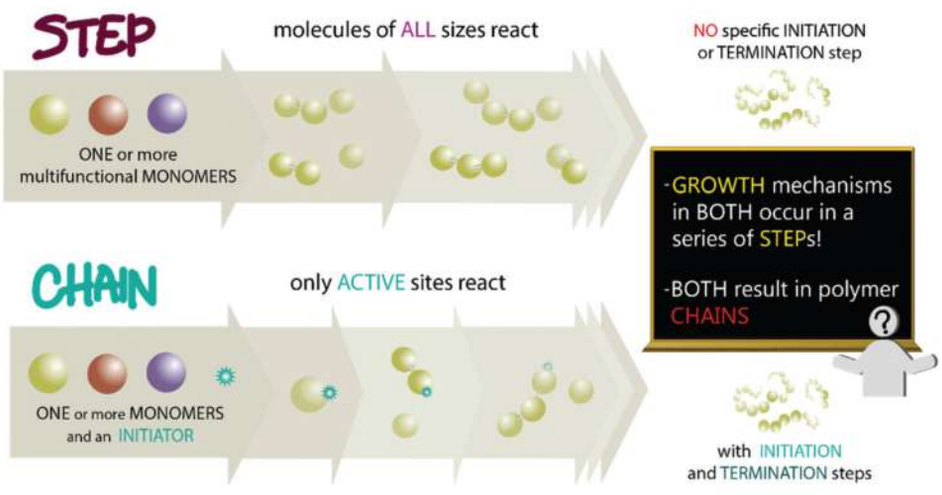


**Fig. 1** Graphical description of the two main polymerization methods, both of which include a series of steps to create polymer chains. Additional arguments for our concerns with the terms "step-growth" and "chain-growth" are highlighted in the text.

| | Growth Mechanism | Monomers reacting with active polymer chains | Molecules of all sizes reacting together |
|---|---|---|---|
| | Reaction Type | Chain reaction | Usually non-chain reaction |
| Stoichiometry | With low-molar-mass by-products | CONDENSATIVE CHAIN POLYMERIZATION | POLYCONDENSATION |
| Stoichiometry | Without low-molar-mass by-products | CHAIN POLYMERIZATION | POLYADDITION |

Fig. 2 Recommendations on polymerization terminology made by SPT in 1994.[4]

between *polyaddition* and "addition polymerization" has created significant confusion because *addition* is employed quite differently in these two sets of terms, having migrated from meaning "chain-growth" under Carothers to "step-growth" under IUPAC.

(2) Furthermore, *polyaddition* is itself a questionable term. IUPAC has defined the term *addition reaction* to be *a chemical reaction of two or more reacting molecular entities, resulting in a single reaction product containing all atoms of all components with formation of two chemical bonds and a net reduction in bond multiplicity in at least one of the reactants*.[7] Thus a *chain polymerization* (as defined in 1994) is a series of addition reactions, while *polyaddition* has a limited definition that excludes chain polymerization.

(3) In the 1994 document,[4] *chain polymerization* was implicitly proposed as a term covering two situations: (i) a generic term encompassing all polymerizations that proceed *via* "chain growth"-type growth mechanisms, *i.e.*, *a chain reaction in which the growth of a polymer chain proceeds exclusively by reaction(s) between monomer(s) and reactive site(s) on the polymer chain with regeneration of the reactive site(s) at the end of each growth step*, and (ii) a specific subclass of chain polymerizations in which there is no condensate, which is the case in most chain polymerizations. The function of the term *chain polymerization* as both a generic term and a specific term has created some confusion. In contrast, in the case of "step-growth"-type growth mechanisms, no generic term was proposed, and filling this void is probably one reason why the term "step-growth" is still widely used. In internal SPT discussions we have used "non-chain polymerization" to cover polymerizations that proceed in a "step-growth" manner, but this is not ideal in that it defines these polymerizations by what they are not rather than providing a definition that alludes to their common characteristics.

(4) Another problem of a similar nature is that all forms of polymerization generate polymer chains, but the term *chain polymerization* might be taken to imply that only such polymerizations do so, and that polyaddition and polycondensation do not. The issue here is that the word "chain" has multiple meanings (in this case *macromolecule* and *chain reaction*, respectively). As stated above, in the current IUPAC definition the chain in *chain polymerization* refers to polymerization occurring through a *chain reaction* process; this may not be immediately obvious. This overlap in meaning creates ambiguity and therefore uncertainty, especially for non-native speakers of English. The current terminology also causes problems when considering reactions such as the polymerization of a dithiol and an α,ω-diene (a thiol–ene polymerization): the polymer forms in a "step-growth" type growth mechanism, but in a radical chain reaction process.

In addition to the specific points listed above, there are additional issues with the 1994 terms that have arisen in the intervening quarter century due to developments in polymer synthesis. For example, there are new polymerization growth mechanisms that fall outside the two traditional categories, and are therefore not covered by any current terminology, recommended by IUPAC or otherwise (detailed below). There are also methods to synthesize polymers from monomers that have been known for decades that do not fall cleanly into either of these traditional categories.

In view of the above situation, it is not surprising that the 1994 terms have not been widely adopted by the polymer community. In fact, we have found no textbooks that employ all four terms recommended in the 1994 document (see below). For this reason, many of us find ourselves using the terms "step-growth" and "chain-growth" in our publications and classes, even though IUPAC has never endorsed these terms, and despite the confusion this situation causes to students learning polymer chemistry. Here, we attempt to outline the dilemmas caused by the terms "step-growth" and "chain-growth" and their various synonyms and subclasses.

This contribution is not a recommendation of terms we think should be used; rather, we simply aim to make clear to the community why we think all present terminology is problematic. No set of terms is perfect, but we believe there must be a better system than the current options. Ideally, we would like to avoid the many shortfalls mentioned above, at the same time employing descriptive accuracy *and* finding simplicity that will be attractive to our diverse community. That this can be achieved is evidenced, for example, by the widespread replacement of the illogical term 'polydispersity index' by the more logical 'dispersity' in the decade since publication of IUPAC Recommendations (by SPT) on this matter in 2009.[8]

## Discussion

### Historical development of terms

Although Staudinger attempted to classify different types of polymerization processes,[9] it was Wallace H. Carothers who first recognized the mechanistic distinction that would eventually lead to the "step-growth"/"chain-growth" classifications. Carothers was dealing with terms for polymers prepared by the two mechanisms in a pioneering period when even the definition of the general term "polymer" was still under discussion.[10] At that time some definitions of polymer stated that a polymer and its monomer must have the same atoms in the same proportions.[9,11] When introducing his theory of the

preparation of high-molar-mass polymers by reaction of monomers bearing functional groups, Carothers proposed the terms "addition or A polymers" for polymers in which the repeat unit has the same molecular formula as the monomer, and "condensation or C polymers" where the repeat unit is different from the monomer(s). Further, he defined two types of mechanisms of polymer growth: (i) "addition polymerizations" leading to A polymers, and (ii) "condensation polymerizations" leading to C polymers. The problem with these terms would soon become clear—by first classifying polymer structures as "A" or "C", then deriving the terms "addition polymerization" and "condensation polymerization" for their growth mechanisms, a direct correspondence between polymer structure and mechanism of polymer growth was created. This system does not effectively capture polymers that can be synthesized in different ways. For example, poly(oxyethylene) is a C polymer when synthesized by polycondensation of ethane-1,2-diol, but an A polymer if it is prepared by ring-opening polymerization of oxirane (Fig. 3).

Soon after Carothers there was the discovery by Otto Bayer at I. G. Farbenindustrie of the formation of polyurethanes from the reaction of diols and diisocyanates.[6,12] This polymerization proceeds like a condensation polymerization, but no low-molar-mass by-product is released, meaning that technically it is an "addition polymerization" according to the terminology of Carothers. In view of this difficulty, Bayer named his process a "polyaddition". This led to confusion because of the similarity of the terms "addition polymerization" and "polyaddition".[13]

Despite these difficulties, the Carothers terminology was adopted for a long time, as reflected by it being the basis of the 1974 IUPAC recommendation,[3] as already mentioned. Of greatest significance was this terminology being used in Flory's influential 1953 textbook.[14]

Flory continued to use the terms "addition polymers" and "condensation polymers", as well as "addition polymerization" and "condensation polymerization", but he was well aware of inescapable problems with them. For example, he wrote: "Whether or not the structural unit differs in composition from the monomer from which it is derived is of no particular significance. The principal justification for the differentiation between condensation and addition polymers (and polymerizations) lies in the marked contrast between the processes by which they are formed". And elsewhere: "The original Carothers distinction between addition and condensation polymers, if applied quite literally, oftentimes fails to serve the desired purpose". Flory also recognized the problem posed by polyurethanes and the like, writing (his italics) "a *polymerization process* which proceeds by a reaction between pairs of functional groups with the formation of a type of interunit functional group not present in the monomer(s) will be regarded as a condensation polymerization". In a polymerization sense this is reasonable, but in a broader chemistry sense it is not, because polyurethane formation does not involve "condensation" as it is generally understood by all chemists. [IUPAC defines the term *condensation reaction* as *a (usually stepwise) reaction in which two or more reactants (or remote reactive sites within the same molecular entity) yield a single main product with accompanying formation of water or of some other small molecule, e.g. ammonia, ethanol, acetic acid, hydrogen sulfide*.[15]]

Flory supported his recommendation as follows: "It is thus appropriate to broaden the definition of condensation polymers ... to include also those polymers which on chemical degradation (*e.g.*, by hydrolysis) yield monomeric end products differing in composition from the structural units". Flory does this because he wants to avoid "the confusion which would arise" if the one polymer were to be categorized in different ways depending on how it was made, *e.g.*, the poly(oxyethylene) example above. This means that, for example, nylon-6 made by ring-opening polymerization of ε-caprolactam, a chain-polymerization process, would still be termed a condensation polymer by Flory. He recognized the incongruity of this, giving the example of poly(lactic acid), but nevertheless still felt compelled to have a classification primarily based on polymer structure rather than mechanism.

The mechanism of chain polymerization was elucidated by Norrish and Brookman in 1939.[16] According to a search of the Chemical Abstracts Service database using SciFinder™, the term *chain polymerization* (not "chain-growth polymerization") was first introduced to refer to these reactions by Hoshino and Iwakura in 1947.[17] It is not clear when the term "step (-growth)" first appeared, but Elias writes that it was in response to the problems in the polymer-based classification of Carothers:[13] "It turned out later that the true distinguishing factor was ... the growth steps. ...Organic chemists therefore started to refer to 'condensation polymerizations' as 'step-growth polymerizations' since the reaction products could be easily isolated and reacted again after several 'steps' whereas those of the known 'addition polymerizations' could not". In other words, the slow rate of "step-growth" polymerizations usually allows for them to be easily stopped and their intermediates isolated, similar to "steps" in preparative synthesis of low-molar-mass organic compounds. Therefore, this use has nothing to do with steps in the mechanistic sense, a fact not widely appreciated today. In this sense this term is "an unlucky choice of words".[13]

Unlucky or not, the term "step-growth" has stuck, becoming part of the dominant classification system of "step-growth polymerization" and "chain-growth polymerization". According to a SciFinder™ search, these terms do not appear

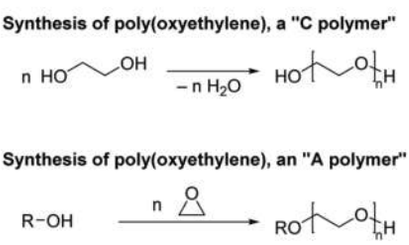


**Fig. 3** Synthesis of poly(oxyethylene) by two different routes.

in the abstracts of papers in the chemical literature before their use in a well-known 1967 textbook by Robert Lenz,[18] although in the textbook the author makes no claim to be introducing a new terminology.

### Terms used in current textbooks

Perhaps because of the problems with all existing terms, and despite the 1994 classification system proposed by SPT, terminology in textbooks continues to vary widely. It is largely pointless to suggest terminology if it is not adopted. We therefore investigated what terms people actually use for basic classification of polymerization reactions. We examined the terms used in approximately 40 textbooks, including multiple editions of some. This allowed us to gauge the influence of the definitions recommended by SPT in 1994 over time. We present our findings in two categories.

First, Table 1 gives terms used in a selection of textbooks on general chemistry and organic chemistry (as indicated in the Category column). The selection is not intended to be comprehensive but represents a range of textbooks that we use in our classes across the world. A careful look at these textbooks reveals that despite most of these books being published in the last decade, the terms recommended in 1994 are completely absent. Some authors discuss polymerization but do not categorize by specific types of polymerization methods, perhaps in part due to confusion over which terminology to use. In terms of book categories, it is evident that general chemistry textbooks almost all retain the 1930s "addition/condensation polymerization" classification. With organic chemistry textbooks there is a strong preference for "chain-growth" and "step-growth".

Overall, it is clear that in undergraduate chemistry textbooks there exists a somewhat chaotic situation regarding classifications: there is no dominant terminology for basic mechanisms of polymer growth, and IUPAC-recommended terminology is absent. This is unlikely to be because it is rejected, but almost certainly because it is not known. This situation is undesirable in several ways. First, it propagates the use of logically flawed terminology. Second, it means that students are confronted by different terms for the same thing, depending upon the textbook used. Finally, how should translators of books into languages other than English deal with a non-uniform situation like this?

It is reasonable to expect more uniform usage of terminology from authors of textbooks on polymer science. Here we examined a selection of these with respect to which basic polymerization terms are used. Our survey is presented in Table 2, again organized by author last name. Rather than attempting to categorize polymer science books, we instead have given their titles, and these cover a full spectrum from synthetic chemistry to engineering and processing.

The first and overwhelming conclusion from Table 2 is that there is no consensus among polymer science textbook writers regarding which terms should be used, nor are there any preferred sets of terms. Invariably the word "step" is used, but in a variety of different ways: "step-growth", "stepwise", "step-reaction" or just plain "step". Sometimes it is partnered with the same variant of "chain" (*e.g.* "chainwise" with "stepwise"), but often it is paired with "addition".

A few authors discuss the 1994 recommendations from SPT. For example, Elias includes a discussion of IUPAC-recommended terms, and he adopts all the terms of Fig. 2 aside from *condensative chain polymerization*, which he spurns on the grounds that "it is illogical to label one subclass with an adjective (*condensative chain polymerization*) but not the other (*chain polymerization*)". We agree with Elias on this point, noted above as issue (3) in the introduction. Instead, Elias proposes "polyelimination",[13,35] which nicely complements polycondensation and polyaddition in a linguistic sense, but seems flawed in several ways: (1) such processes do not meet

**Table 1** Terminology employed for basic polymerization growth mechanisms in various textbooks on general chemistry and organic chemistry

| Author(s) | Year (edition) | Category | Terminology employed |
|---|---|---|---|
| Blackman *et al.*[19] | 2012 ($2^{nd}$) | General | Addition or chain-growth, condensation or step-growth |
| Burrows *et al.*[20] | 2017 ($3^{rd}$) | General | Addition polymerization, condensation polymerization |
| Chang[21] | 2007 ($7^{th}$) | General | Addition reactions, condensation reactions |
| Housecroft & Constable[22] | 2010 ($4^{th}$) | General | Addition polymerization |
| Kotz *et al.*[23] | 2018($10^{th}$) | General | Addition polymers, condensation polymers |
| Mahaffy *et al.*[24] | 2014 ($2^{nd}$) | General | Addition polymers, condensation polymers |
| McMurry *et al.*[25] | 2015 ($7^{th}$) | General | None |
| Bruice[26] | 2014 ($7^{th}$) | Organic | Chain-growth polymerization, step-growth polymerization |
| Bruice[27] | 2016 ($8^{th}$) | Organic | Chain-growth polymerization, step-growth polymerization |
| Carey & Sundberg[28,29] | 1990 ($3^{rd}$) | Organic | None |
| Clayden *et al.*[30] | 2001 ($1^{st}$) | Organic | Polymerizations by carbonyl substitution reactions, polymerization by electrophilic aromatic substitution, polymerization by the $S_N2$ reaction, polymerization by nucleophilic attack on isocyanates, polymerization of alkenes |
| Clayden *et al.*[31] | 2012 ($2^{nd}$) | Organic | None[a] |
| Karty[32] | 2014 | Organic | Chain-growth polymerization, step-growth polymerization |
| Okuyama & Maskill[33] | 2013 ($1^{st}$) | Organic | None |
| Vollhardt & Schore[34] | 2014 ($7^{th}$) | Organic | None |

[a] The relevant chapters from the first edition were removed for the second edition. They remain available as an electronic resource from the publisher.

Table 2 Terminology employed for basic polymerization growth mechanisms in various textbooks on polymer science

| Author(s) | Year (edition) | Title | Terminology employed |
|---|---|---|---|
| Carraher[39] | 2017 (4th) | Introduction to polymer chemistry | Addition polymerization, step-reaction polymerization |
| Carraher[40] | 2017(10th) | Polymer chemistry | Addition polymerization, step-reaction polymerization |
| Cowie[41] | 1991 (2nd) | Polymers: chemistry and physics of modern materials | Addition polymerization, step-growth polymerization; both together referred to as "chain growth mechanism" |
| Cowie[42] | 2007 (3rd) | Polymers: chemistry and physics of modern materials | Addition polymerization, step-growth polymerization; "chain growth" used to mean both forms together and addition individually |
| Dotson *et al.*[43] | 1995 (1st) | Polymerization process modeling | Chainwise, stepwise |
| Elias[35] | 1997 (1st) | An introduction to polymer science | Chain-growth polymerization, step-growth polymerization; polyelimination, chain polymerization, polycondensation, polyaddition |
| Elias[13] | 2005 (2nd) | Macromolecules, vol. 1 – structure and properties | Chain-growth polymerization, step-growth polymerization; polyelimination, chain polymerization, polycondensation, polyaddition |
| Hiemenz & Lodge[44] | 2007 (2nd) | Polymer chemistry | Addition polymers/chain-growth polymerization, condensation polymers/step-growth polymerization |
| Koltzenburg *et al.*[45] | 2017 (1st) | Polymer chemistry | Chain-growth polymerization, step-growth polymerization |
| Nicholson[46] | 2017 (5th) | The chemistry of polymers | Chain polymerization, step polymerization |
| Novak[47] | 1995 (1st) | Organic polymer chemistry: a primer | Chain-growth, step-growth (said to be synonymous with condensation) |
| Odian[48] | 1991 (3rd) | Principles of polymerization | Chain, step (shortenings of chain-reaction, step-reaction) |
| Odian[38] | 2004 (4th) | Principles of polymerization | Chain polymerization, step polymerization |
| Painter & Coleman[49] | 1994 (1st) | Fundamentals of polymer science | Chain/addition polymerization, step-growth polymerization |
| Painter & Coleman[50] | 2008 (1st) | Essentials of polymer science and engineering | Chain/addition polymerization, step-growth polymerization |
| Ravve[51] | 2012 (3rd) | Principles of polymer chemistry | Chain-growth polymerization, step-growth polymerization |
| Rudin[52] | 1982 (1st) | The elements of polymer science and engineering | Chain-growth polymerization, step-growth polymerization (polycondensation sometimes instead) |
| Rudin & Choi[53] | 2012 (3rd) | The elements of polymer science and engineering | Chain-growth polymerization, step-growth polymerization (polycondensation sometimes instead) |
| Stevens[54] | 1999 (3rd) | Polymer chemistry: an introduction | Chain-reaction condensation, chain-reaction polymerization, step-reaction polymerization, step-reaction addition |
| Walton & Lorimer[55] | 2000 (1st) | Polymers | Chain polymerization, step-growth polymers |
| Young & Lovell[36] | 1991 (2nd) | Introduction to polymers | Chain polymerization, step polymerization; polycondensation, polyaddition |
| Young & Lovell[37] | 2011 (3rd) | Introduction to polymers | Chain polymerization, step polymerization; polycondensation, polyaddition |

the usual definition of an *elimination reaction*;[15] (2) "polyelimination" sounds like a degradation process, and indeed the different process of side-chain elimination from polymers is sometimes called polyelimination;[13] (3) a polycondensation could for the same reason be termed a polyelimination. It is telling that Elias explains how the term "step-growth polymerization" is deeply defective, and yet he used it throughout his 1997 textbook due to lack of a better alternative, but then dropped it in his 2005 textbook, opting for the IUPAC-recommended terms *polyaddition* and *polycondensation* instead. Indeed, Elias long ago recognized the terminology dilemma we discuss here.

Young and Lovell also hint at IUPAC influence in two ways: (1) they write of a "modern preference" to use chain and step without "growth", implying that this is a matter of taste; (2) they introduce the step-polymerization subclasses of polycondensation and polyaddition, in accordance with Fig. 2.[36,37] However, they make no mention of IUPAC recommendations, and indeed their usage predates the 1994 recommendations.

Finally, Odian suggests in his latest edition, published in 2004,[38] that the 1994 recommendations from this subcommittee suggested "polycondensation" as a replacement for all types of "step polymerization", neglecting to mention the recommended use of *polyaddition* in polymerizations that follow "step-growth" kinetics but lack a condensate (*e.g.*, polyurethane synthesis). He uses the IUPAC-recommended term *chain polymerization* but does not mention *condensative chain polymerization*.

Several authors in Table 2 use "polycondensation" as a synonym for "step(-growth) polymerization", and thereby fail to acknowledge that such polymerizations need not involve condensation. Ironically, nearly all textbooks do the one thing that SPT neglected to do in 1994—provide generic terms. The problem is that they have all used some combination of the old, flawed terms. We strive to remedy this problem.

## Problems arising from translations of "step-growth" and "chain-growth" into other languages

The official language of IUPAC is English, so we focus here on terminology in English. However, it is worth noting that the terms "step-growth" and "chain-growth" present additional problems for non-native English speakers. While difficulties and ambiguities arise with translations of many technical terms, we find that a clear and precise definition in English tends to reduce problems in translation. In contrast, the lack of clarity and precision in "step-growth" and "chain-growth" in

English appears to become further magnified when translated into other languages.

For example, in German "step" is translated as "Stufe", which can also mean "stair", although in the context of a reaction step the term "Schritt" is used. The Czech language has the same translation, where "step" is translated as "stupeň" but "krok" is used for a reaction step. A related problem arises in Spanish, where the word "step" has been translated into "etapas" (stages). The word "etapas" implies a sequential evolution and can result in thinking it is related to a chain polymerisation reaction. Problems with the word "chain" arise in other languages such as French, where "enchainment" is used to describe the concept of polymerisation (enchaînement = linkage). This linkage process implies a sequence of steps (étapes), meaning steps or stages, leading to confusion when the two basic polymerization mechanisms are discussed.

Similar problems arise in languages outside of the Indo-European family of languages. In Chinese, both the meanings of "step by step" (逐步) and "stair-like" (阶梯式/階梯式) are used in the translation of "step-growth". For "chain-growth", both the meanings of "long chain" (链式/鏈式) and "a sequence of reactions" (连锁/連鎖) are used in the translation. Even for the same meaning, different Chinese characters are also used, making the situation even more complicated. In Japanese, step-growth translates directly as step-growth (段階成長, dankai-seichou or 逐次, chikuji), and chain-growth translates as sequential (連鎖, rensa). In the three related languages of Malay, Brunei, and Indonesian, "step-growth polymerization" is "pempolimeran/pempolimerisasi langkah", where "langkah" translates as "footwork while walking." "Chain polymerization" is "pempolimeran/pempolimerisasi rantai" where "rantai" means chain of strands. In other languages such as Thai, the English terms are often used but spelled phonetically, perhaps avoiding some of the confusion generated in other languages when translating directly.

This brief analysis shows how the currently dominant terminology can lead to various problems when translated into different languages. However, we stress that the problem here is fundamentally one of consistent use of logically sensible, English-language terms. We anticipate that more sensible terms in English could avoid some of the problems that arise in other languages.

## Polymerizations that lie outside of traditional growth mechanisms

There are some reactions that unambiguously generate macromolecules but cannot be fitted into any of the four classes of Fig. 2. Equally, there are other polymerization processes that can be fit into this categorization only by unnatural extension of the meaning of terms inconsistent with their IUPAC definitions. Thus, although IUPAC defines *polymerization* as the *process of converting a monomer or a mixture of monomers into a polymer*, there are situations where, under the current terminology of Fig. 2, monomers can be converted into polymer without the process formally being in a class of polymerization. This clearly warrants some consideration.

The first situation, reactions that produce polymers but do not fit into any class in Fig. 2, arises from iterative processes. For example, a laboratory solid-phase peptide synthesis (SPPS) unambiguously generates a macromolecule through reaction at a specific site on a macromolecule, with generation of low-molar-mass by-products, but by a repetitive series of coupling and deprotection reactions.[56] No chain reactions occur, so SPPS cannot be labelled a *chain polymerization*, but neither is it a *polycondensation* because reactions do not occur between molecules of all degrees of polymerization. A related example is reversible addition–fragmentation chain transfer single-unit monomer insertion (RAFT SUMI), where a chain reaction takes place between propagating species and monomers without generation of low-molar-mass by-products to add a single monomer unit to an existing oligomer or polymer.[57] However, it cannot be labelled a *chain polymerization* because no single RAFT SUMI reaction step leads to formation of a macromolecule. Rather, much like SPPS, RAFT SUMI is a sequence of separately conducted (chain) reactions, each of which appends a single monomer unit to the polymer chain. Analogous problems in terminology arise in dendrimers, which are also synthesized by iterative processes.[58]

The second situation, polymerizations which require extending the definitions in Fig. 2, arises because *condensation* and *addition*, as defined by the IUPAC recommendations of 1994,[15] do not exhaust the possible ways of generating chemical bonds. If *addition* is defined as consistent with chemical intuition as *a reaction giving a net reduction in bond multiplicity in at least one of the reactants*, it is clear that there could also be polymerization reactions in which bond multiplicity remains constant[59] or increases.[60] Polymerization can also occur *via colligation*, the generation of a bond by the combination of two radicals, or *coordination*, where the two electrons in a newly formed bond come from only one of the precursor molecules. An example of polymerization by colligation is Gilch polymerization and related reactions,[61,62] which proceed predominantly through the reaction of biradicals. Gilch polymerization may proceed to a large degree by reactions between molecules of any degree of polymerisation in which bonds are formed by radical combination.[63]

In these two situations, the current terminology can only be made to fit by disregarding part of the definition (interpreting *chain reaction* so broadly as to make it meaningless) or interpreting it in a different way in polymer chemistry than in physical organic chemistry (using a truncated form of the IUPAC definition of *addition* that omits the stipulation on bond multiplicity).

## Moving forward

In 2019, IUPAC approved a project with the goal of recommending a solution to the terminology problems discussed here. Many of the authors on this contribution are members of the task group for this project.[64] Specifically, we seek to provide an umbrella term that captures the current IUPAC endorsed terms of *polycondensation* and *polyaddition*, which our analysis here indicates could be a reason for the ongoing

terminology problem. We also aim to provide a similar structure, including an umbrella term, for *chain polymerizations* that encompasses those with and without condensates. Finally, we will suggest terms for reactions that generate polymers but currently cannot be classified using any of the existing polymerization terms. We welcome input from the community on this matter.

## Conclusion

Here we have outlined our concerns with the terms "step-growth" and "chain-growth", which remain in use, along with several related terms, despite their flaws and the deprecation of their use by IUPAC in 1994. An analysis of terms used historically and in current textbooks was particularly illuminating: despite a clear understanding for many decades of the two types of basic mechanisms of polymer growth, we as a community still have not agreed on terms to describe these two cases. The present use of similar-sounding terms with different meanings adds to the confusion, and this lack of clear and logical terminology causes problems in translating the terms from English into other languages. Furthermore, there are examples of reactions or processes in the field of polymer synthesis that produce polymers, but there are no terms that describe these polymerizations. As a group of polymer scientists, we are working to find a solution. We welcome input from the community as we attempt to remedy these dilemmas. Please let us know your thoughts by emailing us at polymer.terminology@iupac.org. Comments will be read until the end of 2022.

## Conflicts of interest

There are no conflicts to declare.

## Acknowledgements

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Kindly refer to https://iupac.org/reconsidering-terms-for-mechanisms-of-polymer-growth-the-step-growth-and-chain-growth-dilemma/ for more details. This paper does not recommend new terms. Instead, the members of SPT working on this project seek suggestions from the community on how to provide clear, simple, and consistent terms to describe the two major mechanisms of polymer growth and their subclasses. They ask that ideas, concerns, and suggestions be sent to polymer.terminology@iupac.org.

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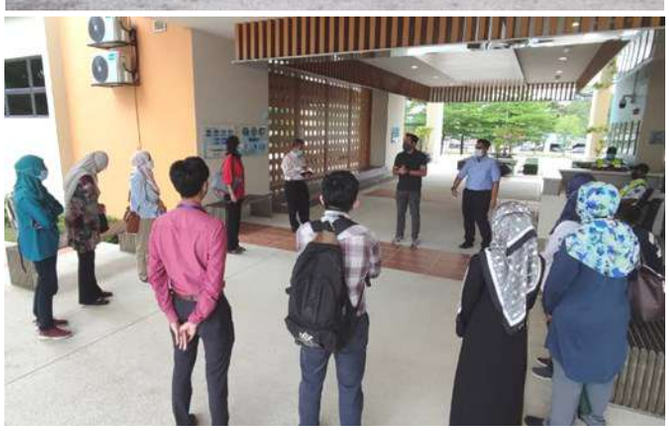
# IKM Division of Analytical Chemistry 2021 - A year in Reflection

Reflecting on 2021, it has been a challenging year for most of us as we continue to endure the unprecedented times of COVID-19 pandemic. Malaysia also went into several lockdowns in 2021. Nonetheless, we at IKM Division of Analytical Chemistry managed to plan our activities and successfully conducted them with the strong supports of our committee members.

One of the highlights was the webinar "Meet Specialists from UK & Malaysia" organised by SMK Seri Bintang Utara and IKM. One of the division members, Dr. Tan Ming Yueh, was also invited as one of the speakers to deliver a talk on "Biochemistry in our Daily Life" on 14th of July 2021. The webinar was a success with 103 Form Four secondary students attended the session. In this 50 mins presentation, participants were exposed to different applications of biochemistry in the daily life, such as in pharmaceutical, food processing, technologies and etc. as well as the different education pathways after SPM and the future career prospects with a Chemistry or Biochemistry degree.


The second major activity was our technical visit to Pantai 2 Sewage Treatment Plant, Indah Water Konsortium (IWK) Kuala Lumpur on 12th of November 2021. IWK is Malaysia's national sewerage company, owned by the Minister of Finance Incorporated to develop and maintain a modern and efficient sewerage system for all Malaysians. A total of 13 IKM members from government agencies and local universities joined this visit. The team arrival was well received by IWK management team led by Mr. Aqiel Azmi Khair. The programme began with safety briefing before entering the sewerage treatment plant area and followed by the IWK corporate video presentation which explained the development of Pantai 2 Sewage Treatment Plant.

And earlier this year, the Chemistry Programme, Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM) and IKM Division of Analytical Chemistry had jointly organised a webinar entitled "Industry in the Classroom" on 12 January 2022. The sharing session by industry subject matter experts in the application of statistics and analytical chemistry at the workplace was led by a second year UKM Chemistry Programme undergraduate Shaarvin Elangovan and was advised by ChM Dr. Nurfaizah Abu Tahrim and ChM Dr. Nadhratun Naiim Mobarak. The objective of the programme was to provide an exposure to Chemistry Programme students on the importance of the field of statistics and analytical chemistry in

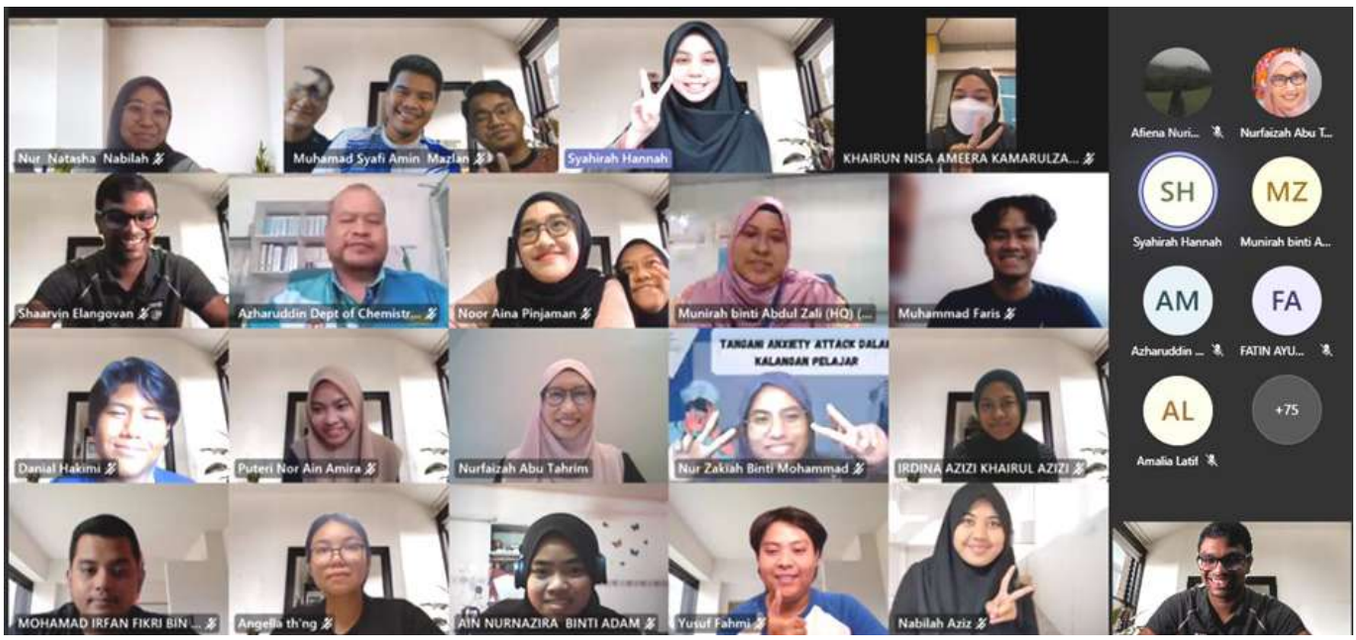
industry. Furthermore, students also learned how the contents can be applied and implemented in the chemical as well as other industries. The invited speakers were Scientific Officers from the Department of Chemistry Malaysia -

(i) Presentation 1: Method Validation for Chemical Agent Warfare (CWA) by ChM Azharuddin Bin Abd Aziz

(ii) Presentation 2: Method Validation for Water Analysis according to APHA 3125 by ChM Munirah Binti Abdul Zali.

The webinar gathered a total of 111 participations mainly from the Chemistry undergraduate community and received positive feedbacks from the participants.


Despite the challenges in times of COVID-19, with the support and determination from our members, the above-mentioned plans/activities were made possible. We will continue to expand the division's activities with far-reaching effects in 2022.



# Forum on Chemistry & Climate Change (C&CC)

**Forward**

The increase in greenhouse gases, particularly carbon dioxide and methane, in the atmosphere since the industrial revolution in the 1950s, has resulted in global warming in a significant way as to cause changes in climate patterns all over the world. The so-called climate change is going to alter global climate patterns in such a way the lives on earth may be seriously threatened. To date, it is estimated that the global surface temperature has increased by 1.15ºC over that of the pre-industrial revolution. In recent years, the incidents of extreme weather have also increased significantly. Extreme weathers such as extreme temperature and drought, exceptional rainfalls resulting in flooding and landslides, very heavy snowfall and other forms of precipitations, and increasing incidents of powerful storms such as tornadoes, hurricanes and typhoons, are getting more frequent and causing great havocs to habitats and human lives. If this global warming is allowed to go on unchecked, humans will be facing the greatest climate disasters of all time.

The governments of the world are now working hard to find ways to solve, or at least reduce and mitigate this climate change. The recent UN Conference of The Parties (COP) 26 held in Glasgow, United Kingdoms, had come out with a declaration asking governments of the world to reduce greenhouse gases emissions. Pledges are being made by different governments to reach net-zero emission or be carbon neutral by certain time frames. The target is set at a maximum global warming of 1.5ºC by 2050. The question is how are we going to do this. Can Chemistry play a significant role in finding a solution to climate change?

On the 26 March, IKM brought together an invited speaker and five keynote speakers to talk about climate change from various perspectives to raise awareness, initiate discussions and inspire chemists in attendance to bring about change from their respective areas of expertise. The followings are the presentation highlights:

**Welcome & Introductory Remarks**

**Datuk ChM Dr Soon Ting Kueh, *President, Institut Kimia Malaysia***

On behalf of Institut Kimia Malaysia (IKM), I would like to welcome all of you to this Forum on Chemistry & Climate Change.

The main culprit of climate change is carbon dioxide in the atmosphere. This is due mainly to the use of fossil fuels as a source of energy for power generation and transportation. Other human-induced activities such as deforestation, land clearing for agriculture and degradation of soil, also contributed significantly to the release of carbon dioxide into the atmosphere. The obvious solution is to replace fossil fuels with other renewable energies such as solar, wind, geothermal and even nuclear. Chemistry plays a very important part in the development of these renewable energy resources. In fact, the development of these renewable energy resources is so advanced that they are gradually replacing fossil fuels in the energy supply system. Research work on new energy sources such as green hydrogen and induced fusion, are very promising and they may soon be available. Beside working on reducing carbon emission, scientists are also working on decarbonisation, removing carbon dioxide from the atmosphere. A lot of research are being done now to find ways for the large-scale sequestration of carbon dioxide from the air at a reasonable cost.

So, we have invited a number of top experts to share with us their knowledge and expertise on chemistry and climate change. We are very fortunate to have them to discuss and deliberate various issues and challenges related to climate change. I am sure that we would benefit tremendously from the deliberations at this Forum.

Thank you and have a good Forum.

**Invited Lecture | Climate Change: Chemistry Comes to The Rescue**

**Assistant Professor ChM Dr Yvonne Choo Shuen Lann, *Xiamen University Malaysia***

Chemistry is often perceived as part of the problem rather than the solution because greenhouse gas (GHG) emissions such as methane, carbon dioxide, nitrous oxide and water vapor are derived from chemicals – petroleum is a chemical fuel used for transportation and various chemical reactions are involved in the production of goods from raw materials as well as the breaking down of materials at a later stage. To counterclaim and reinstate chemistry's crucial role in climate change, the presentation showcased three of many strategies based on the logic that efforts of reducing/control GHG emissions could positively impact climate change.

**Strategy 1: GHG Conversion.** Song et al from the Korean Advanced Institute of Science and Technology (KAIST) reported the development of an effective and economically more viable molybdenum-doped nickel nanocatalyst capable of recycling methane and carbon dioxide into synthetic gas (hydrogen and carbon monoxide) [1]. Calvinho et al from Rutgers University successfully developed nickel phosphide-based electrocatalysts that can convert carbon dioxide into polymer precursors (methylglyoxal and 2,3-furandiol) that could subsequently be used to make plastics, fabrics, resins and other products [2].

**Strategy 2: Carbon Dioxide Capture and Short Term Storage**. Voskian and Hatton from the


Massachusetts Institute of Technology (MIT) developed an interesting, significantly less energy-intensive absorption and release technology whereby large specialised batteries could absorb carbon dioxide from the air at any concentrations while charging up and releasing it while discharged. The stacks of electrodes used are coated with polyanthraquinone and are composited with carbon nanotubes [3]. Lim et al from the Korea Maritime and Ocean University (KMOU) demonstrated the effectiveness of cage-like organic hydroquinone clathrates for the capture and recovery of carbon dioxide, nitrous oxide and carbon dioxide-nitrous oxide gas mixtures [4].

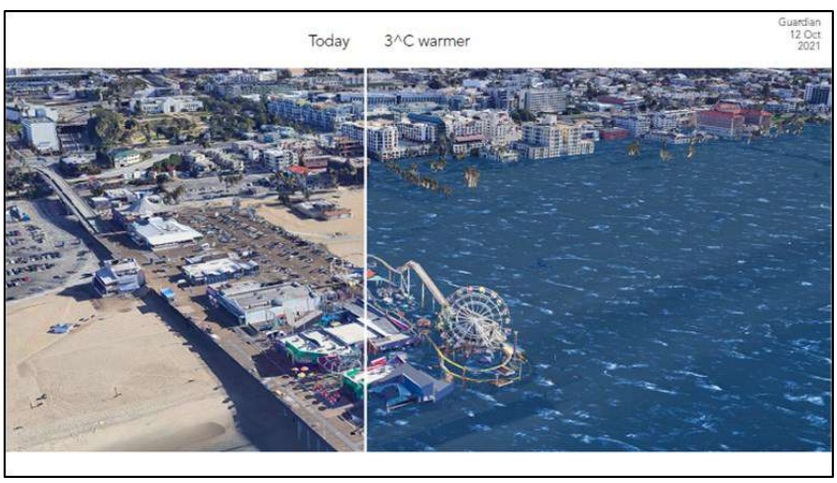
**Strategy 3: Greener Energy Alternatives**. Artificial photosynthesis is a process that mimics nature photosynthesis by converting sunlight, water and carbon dioxide into more than one type of fuel (e.g. hydrogen gas, methanol, ethanol, etc.), dramatically changing the renewable energy landscape. At present, "these technologies face significant engineering challenges to produce fuels efficiently and economically" [5].

Although chemistry may be a contributor to climate change, it can be part of the solution. Chemists could work hand in hand with other key players of climate change (e.g. policy makers, engineers, technologists, etc.) towards net-zero carbon emissions by 2050. Ultimately, it is a race against time and there is no time to lose!

**Keynote Lecture 1 | COP 26: Climate Change and Its Global Impact on Economy and Society**
**Datin Seri Sunita Rajakumar, *Climate Governance Malaysia***

With increased pressure leading up to the United Nations Framework Convention on Climate Change (UNFCCC)'s Conference of the Parties (COP26) in Glasgow last November, businesses (in the global context) have to demonstrate resilience and the ability to transition in support of 2015 Paris Agreement's goals. Although many businesses and countries have since declared some form of long-term commitment towards net-zero emissions, action have to be stepped up in order to match the climate ambitions and there needs to be a smooth transition with a "Whole of Society" and "All of Government" approach. With that being said, CEO Action Network (CAN) and Climate Governance Malaysia have come together to facilitate a robust discussion through roundtable sessions between all stakeholders.

In addition, the presentation also highlighted real risks faced by various regions of the world ranging from the collapse of Conger ice shelf in Antarctica [6] to the death of nine-year-old Ella Adoo-Kissi-Debrah due to air pollution exposure [7]. and the impact of a 3ºC temperature increment. It is apparent that drastic actions are required by every segment of our society and economy to meet the real risks and opportunities we face today.

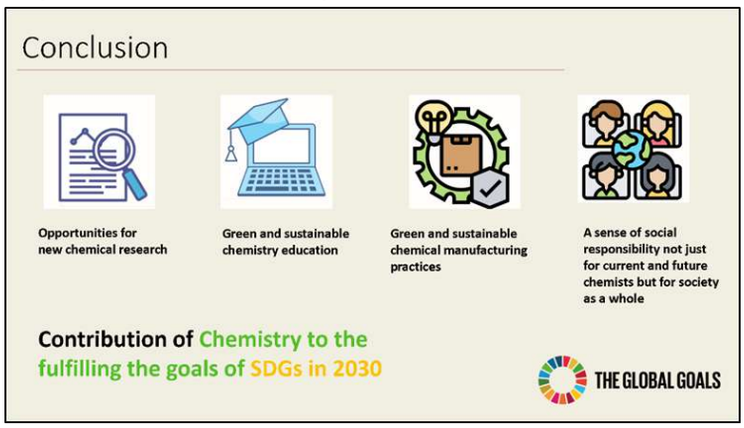



**Keynote Lecture 2 | Chemistry and Sustainable Development Goals in Malaysia**
**by Associate Professor ChM Dr Collin G. Joseph and Professor Datuk ChM Ts Dr Taufiq Yap Yun Hin, *Universiti Malaysia Sabah***

Sustainable Development Goals (SDGs, 2016-2030) is the development policy continuation of the Millennium Development Goals (MDGs, 2000-2015) and has become the go-to benchmark for awarding research grants, development contracts and drafting government policies. In spite of SDGs' growing popularity, the concept and long term benefits are not as well known, and the lack of knowledge becomes apparent when those in specialized disciplines questioned chemistry's involvement in SDGs. To address this, the presentation highlighted seven SDGs with emphasis on chemistry's contributions in achieving them.

**Goal 2: Zero Hunger**. Chemistry contributes to the development of drought protection crops, phosphate recovery and reuse, protection against pest infestation and active packaging to prevent food spoilage.

**Goal 3: Good Health and Well-being**. Chemistry contributes to the development of drugs and medical diagnoses, the application of green and sustainable chemistry to help eliminate and reduce chemical pollution that could impact human health.




**Goal 6: Clean Water and Sanitation**. Chemistry contributes to the development of water purification technologies, bringing forth new and lower cost desalination processes. In addition, the chemical industry can implement manufacturing practices that minimise the usage of water as well as waste management practices to help avoid pollution.

**Goal 7: Affordable and Clean Energy**. Chemistry contributes to the development of new materials for renewable energy (e.g. battery technology, energy storage), cleaner fuel and green technologies. Nearly all renewable energy sources and technologies depend on innovations in chemistry to become more efficient, affordable and scalable.

**Goal 9: Industry, Innovation and Infrastructure**. Chemistry contributes to the various technologies and materials required for sustainable construction and urban mobility such as insulation, paints, adhesives, sealants, lightweight materials and smart interior lighting and cooling systems, etc.

**Goal 12: Responsible Consumption and Production**. Chemistry helps to improve the quality and efficiency of production processes, minimize energy and reduce the life cycle impacts of consumption. By recycling and reusing molecules, the loop in chemical manufacturing could be closed realizing a circular economy.

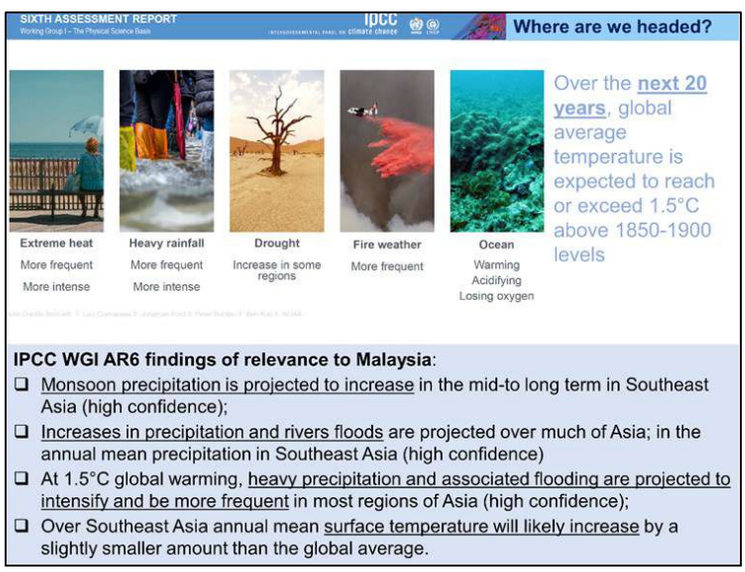
**Goal 13: Climate Action**. Chemistry can play a key role in the advancement of atmospheric chemistry to enable a better understanding of the causes of global climate change and the prediction of its extent and impact. Furthermore, chemistry contributes to the design principles of green and sustainable chemistry (education and policy) and the "development of solutions that will enable other sectors to strengthen their resilience to climate-related risks" [8].

**Keynote Lecture 3 | Climate Change Mitigation and Adaptation: An Imperative for Advancing Scientific Action**

**Professor Dr Joy Jacqueline Pereira, *SEADPRI-Universiti Kebangsaan Malaysia***

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [9] released in 2021 highlighted a 1.1ºC increase in the global average temperature, with each of the past four decades being the warmest on record since preindustrial times. The report further confirmed human activities are the primary cause of climate change. Climate change is already affecting many weather and climate extremes in all regions (heatwaves, heavy precipitation, drought, tropical cyclones) and if no effective climate actions are put in place, global warming would reach 1.5ºC as early as the next decade. As to how ready Southeast Asia is in the face of extreme weather, it is found to be at a low-medium level of readiness for extreme rainfall and heat [10].

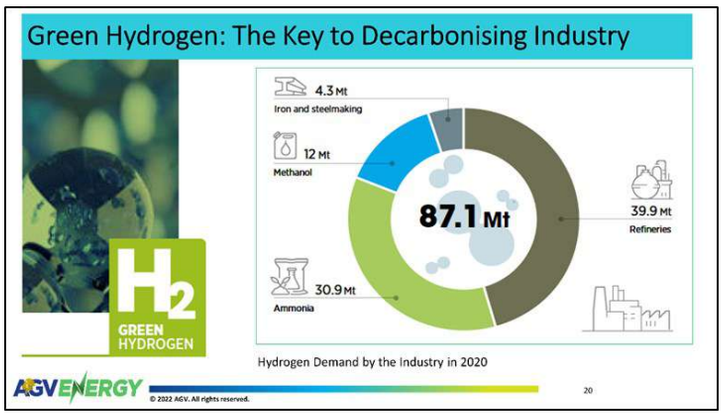
By limiting global warming to 1.5ºC instead of 2ºC, many benefits would be expected, some of which include lowered impact on biodiversity and species as well as less extreme weather where people live, however, it would require transformative actions at an unprecedented scale. For instance, deep emission cuts in all sectors, deployment of a range of technologies, behavioural changes as well as increased investment in low carbon options. More specifically, carbon dioxide emissions will need to be reduced by 45% by 2030, reaching net-zero around 2050. It is important to note that "advancing scientific action is imperative for accelerating climate change mitigation and adaption, to enable equitable transitions and build resilient societies".




**Keynote Lecture 4 | Green Hydrogen Economy and Its Impact on Climate Change**

**Datin Dr Vijayalakshmi Samuel, *AGV Energy & Technology Sdn. Bhd., Malaysia***

In order to counteract the effects of rampant and uncontrolled uses caused by carbon-intensive economies, the world will need to shift to a Low-Carbon Economy or Hydrogen Economy to ensure net-zero is achieved by 2050. Hydrogen economy refers to a proposed system, in which, hydrogen is produced from carbon-dioxide-free sources and is




used as an alternative fuel [11]. Hydrogen being a versatile energy carrier with exceptional energy density can therefore be used to substitute fossil fuel and act as an energy source to decarbonise transportation, electricity and heat production sectors, etc.

Despite being a green fuel, hydrogen is given various colouring labels based on its production source, aptly named the Hydrogen Rainbow encompassing grey (from Steam Methane Reforming), brown (from coal gasification), blue (from natural gas and supported by carbon capture and storage) and green hydrogen, respectively. Green hydrogen which can be obtained via the use of electrolysis (e.g. proton exchange membrane (PEM) electrolysis, alkaline electrolysis or solid oxide electrolysis), is predicted to play a significant role in reducing GHG globally.

The value and potential of investing in hydrogen economy has culminated in various large scale green hydrogen projects around the globe, notably in Japan, Australia, China and Spain. Whilst the transition to a hydrogen economy would create various job opportunities in different sectors, it is not without its challenges, ranging anywhere from the current technology and cost, to infrastructure and safety.

**Keynote Lecture 5 | Tropical Forests: Its Role in Carbon Sequestration and Climate Change Mitigation**

**ChM Dr Jeyanny Vijayanathan, *Forest Research Institute Malaysia***

Carbon sequestration is a process known to reduce the amount of carbon dioxide in the atmosphere by capturing and storing atmospheric carbon dioxide. Since tropical forest has the capability of sequestering carbon in their biomass and soils, efforts in promoting good forest health will increase carbon sequestration in forests. This presentation highlighted the effects of climate change in the Malaysian context and the mitigation efforts that can be applied in the forestry sector towards harmonizing the need for sustainable utilization, whilst conserving planetary health.

In 2016, Malaysia's GHG emission was at 316,833 Gg $CO_2$ eq without Land Use, Land-Use Change and Forestry (LULUCF) out of which 76% (241,344 Gg $CO_2$) can be attributed to GHG removal in LULUCF, a net sink [12]. Afforestation (planting trees where there were no forest before), reforestation (restoring forest areas and woodlands which once existed but were deforested), conservation, agroforestry and sustainable forest management are some of the climate change mitigation efforts discussed that would make a difference the long run.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Report prepared by,
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# Perspective on Gas Chromatography Application in Forensic Fire Debris Analysis

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Forensic fire investigation involves determining the origin and cause of the fire, which is supported by detecting ignitable liquid in a fire residue or identifying ignitable liquid seized surrounding the crime scene (Stauffer et al., 2008). The ignitable liquid describes liquids like gasoline and diesel that can initiate or propagate a fire. Amongst the variety of ignitable liquids, gasoline is used the most to initial a hostile fire. Destroying physical evidence by fire is most preferred by the criminal attributed to the low cost of execution and effectiveness. For instance, bloodstains often seen in a murder case can be damaged badly by the intense heat of the fire (Bastide et al., 2021). A burnt carcass also makes an entomological analysis challenging for determining the post-mortem intervals (Malainey & Anderson 2020).

Various advanced chemical instruments have been proposed for analysing the fire debris or liquid sample seized at the crime scene (DeTata, 2019). For instance, Pandohee et al. (2020) demonstrated the benefits of using a two-dimensional gas chromatography-flame ionisation detection (2D-GC) in identifying the type of aged fuel for arson investigations. The authors claimed the proposed analytical method was robust, fast and sensitive. Despite 2D-GC was also reported to be capable in resolving an overwhelmingly larger number of peaks than the one-dimensional gas chromatography (1D-GC) technique, the peak capacity of 2D-GC does not generally exceed those obtainable from 1D-GC within the same period of analysis and the same minimal detectable concentration (Blumberg et al. 2008).

Gas chromatography-mass spectrometry (GC-MS) nevertheless is still the most applied technique in forensic debris analysis, attributed to two rationales. Firstly, many references and background studies on analysing fire debris have been based on using GC-MS. For example, the essential procedures in interpreting GC-MS data of fire debris are outlined by the American Standards of Testing and Materials (ASTM) 1618-19. Secondly, the operational and maintenance cost of a unit of 1D-GC is also relatively lower than that required by a 2D-GC.

Typically, GC-MS analysis can be performed either using a targeted or untargeted approach (Gonzalez-Riano et al., 2018; Penalver et al., 2021). Figure 1 illustrates the differences between the two approaches. The former concerns only a small number of peaks (i.e. compounds) that are known to be associated with the studied sample. In fire debris analysis, only compounds useful in identifying ignitable liquids are targeted, e.g. C3-alkylbenzenes and naphthalene are always selected for detecting petrol. In contrast, untargeted analysis usually considers more variables (i.e. peaks) than the targeted one. It can be executed using a peak table or pixel-level GC-MS data (Sudol et al., 2020). Pixel-level data is prepared by exporting all retention time points from the GC-MS system; meanwhile, peak table data comprises peak area/ height and retention time ranges of selected peaks.

Despite the fact that targeted GC-MS analysis is the classical approach for detecting and identifying ignitable liquid (Lennard et al., 1995), recent efforts have been devoted to studying the feasibility of an untargeted approach in forensic fire debris analysis, e.g. Pasternak et al. (2022) and De Figueiredo et al. (2019). Since the untargeted analysis involves more variables, making the visual interpretation notorious challenging. Consequently, untargeted GC-MS analysis is often coupled with the chemometric approaches that are proven helpful in processing high dimensional chemical data (Popovic et al., 2019).

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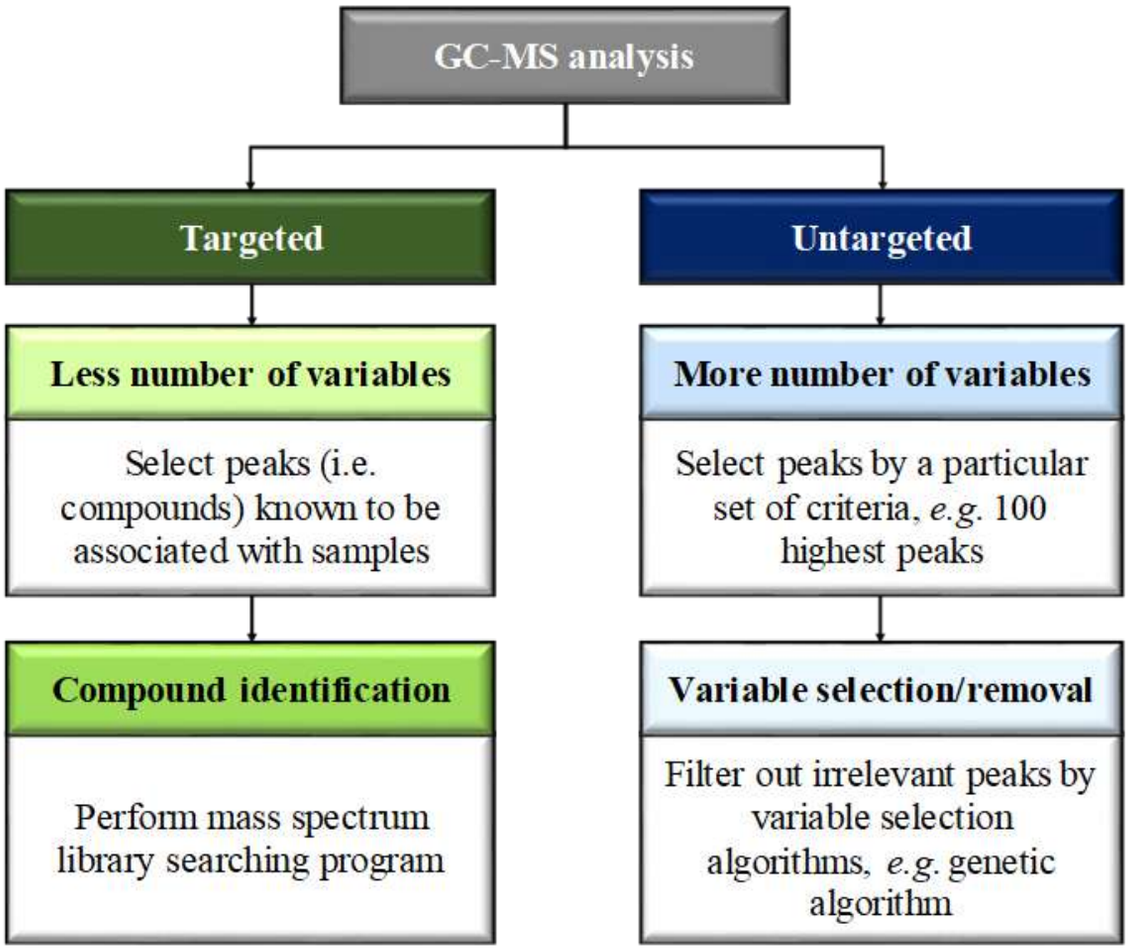


Figure 1 Targeted versus untargeted approach in performing GC-MS analysis


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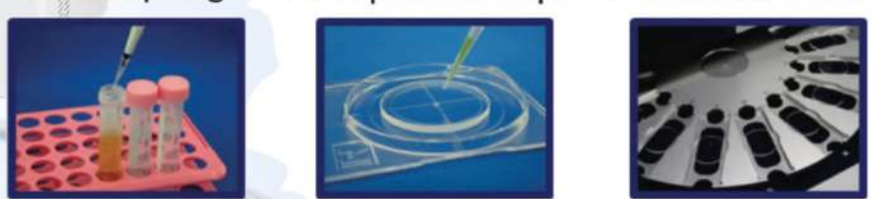

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# Virtual 2-Days Seminar On Safety in the Laboratory and Risk Assessment

Jointly Organized by Jabatan Kimia Malaysia (KIMIA Malaysia) and
IKM Chemical & Occupational Safety & Health (COSH) Committee

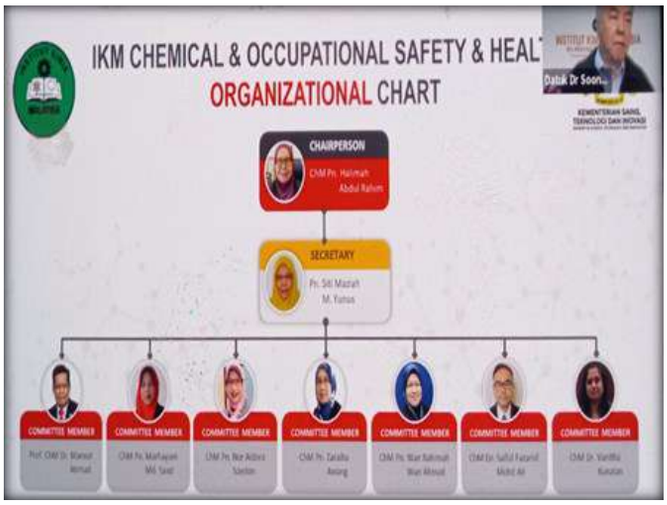
A two-days webinar on "Safety in the Laboratory and Risk Assessment" was successfully held on 10th and 11th February 2022. The webinar was jointly organized by Chemical & Occupational Safety & Health Committee, Malaysian Institute of Chemistry (IKM) and the Department of Chemistry Malaysia (KIMIA Malaysia). The webinar was conducted *via* the Zoom platform and streamed live *via* IKM Facebook. Up to 400 participants from higher learning institutes and private companies as well as government agencies attended the two-days virtual seminar. The webinar received many positive responses from the participants through the comments in chat box and Facebook.

The session on the first day began with a welcoming speech and opening remarks by the President of Malaysian Institute of Chemistry (IKM), Datuk ChM Dr Soon Ting Kueh. He expressed his gratitude towards the great


initiative in making the virtual seminar possible by the COSH committee members for the benefit of IKM members. The webinar started with the first lecture on "Basic Hazard Identification, Risk Assessment & Risk Control (HIRARC)" by Prof. ChM Dr. Mansor Ahmad who is also the committee member of the COSH IKM and former lecturer in the field of polymer chemistry from Universiti Putra Malaysia (UPM).

His lecture covered the HIRARC implementation in identification of factors that may cause risk to workers toward an accident, to consider the possibility of hazards that may occur under any circumstances and conditions and enable workers to plan, introduce and monitor preventive measures against the risks of occupational injury. The webinar continued with the second lecture on "Risk Assessment in the Laboratories" by ChM Mohd Norhafsam bin Maghpor who is a Technical Expert III from National Institute of Occupational Safety and Health (NIOSH). His lecture encompassed creation of awareness to recognise and control hazards in the workplace by setting up the risk management standards based on acceptable safe practices and legal requirements. On the second day, the webinar started with a lecture on "ISO 45001 Implementation at the Department of Chemistry Malaysia" by ChM Aidil Fahmi bin Shadan, a senior chemist from the Department of Chemistry Malaysia. ChM Aidil is the Head of Occupational, Health and Safety Section at the Department of Chemistry Malaysia. His lecture was on the ISO 45001 which is a global standard for Occupational Health and Safety Management Systems that provides a practical solution to improve safety and health of both employees and other personnel at workplace.

The second lecture on "Laboratory Safety Implementation at the Department of Chemistry Malaysia" was given by ChM Zawiyah binti Zainal Abidin from Department of Chemistry Malaysia who is currently serving in the area of occupational, health and safety at the Department

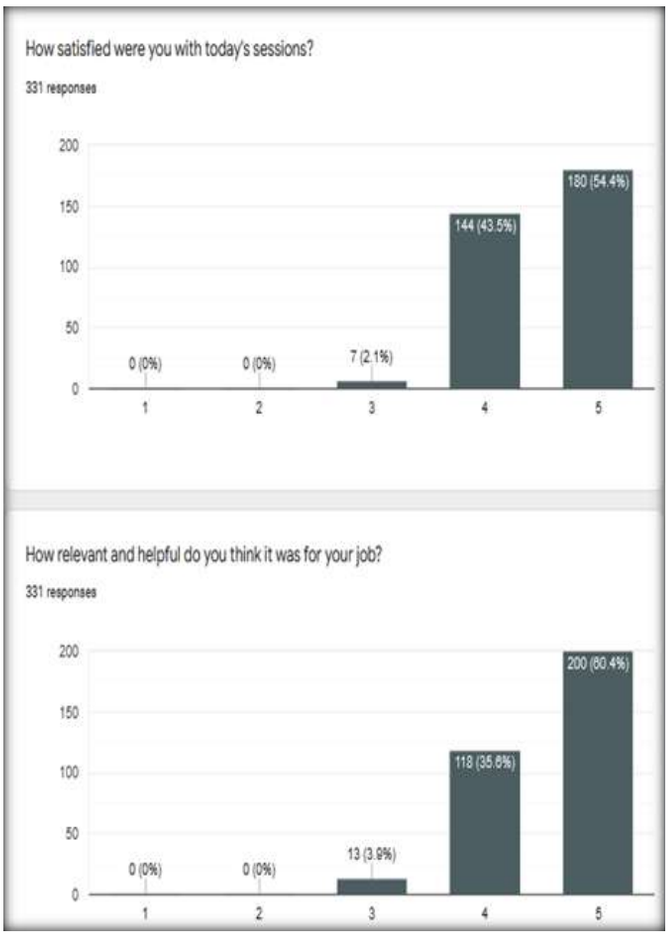


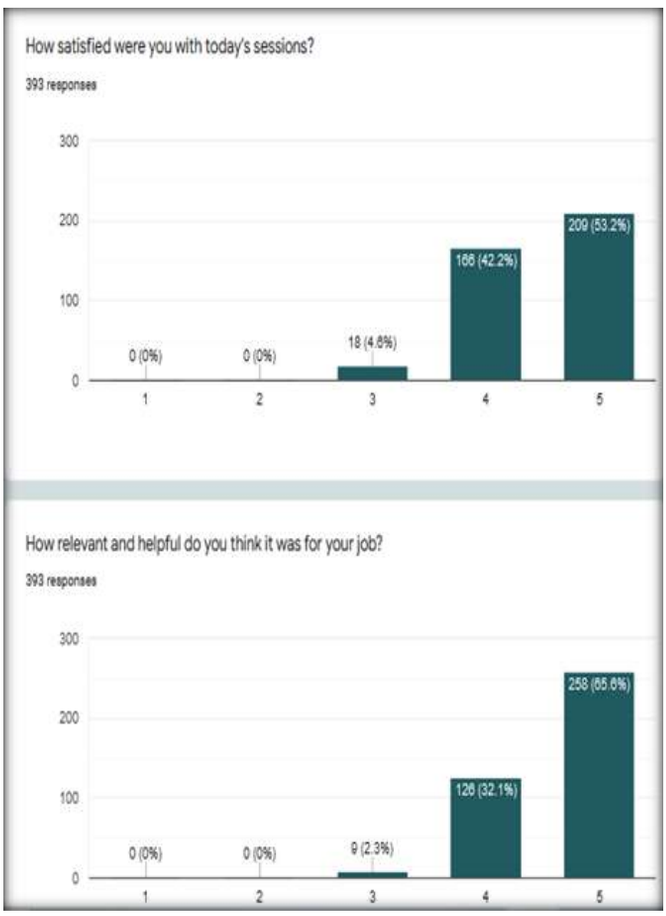

of Chemistry Malaysia. Her lecture include the hazards and safety procedures for activities involving hazardous work in the laboratory or any workplace, as well as, information systems, such as Safety Data Sheets for hazardous chemicals used in the laboratory to avoid any accidents.

The final lecture on "Laboratory Management of Covid-19 Samples" was given by ChM Dr. Sharmilah a/p Kuppusami who is the Head of Alcohol and Clinical Toxicology Section at Department of Chemistry Malaysia. Her lecture covered the safe handling of Covid-19 samples during toxicological analysis. The webinar was followed by an online quiz and prizes were given to 20 winners who answered all the questions correctly in the shortest amount of time. The webinar participants were provided with an e-Certificate.

The following bar charts showed the participants' responses for the two-day webinar. More than 95% of the participants were satisfied with the topics shared on both days and found the webinar to be relevant and helpful for their job and work environment. This two-day webinar received encouraging response from the speakers and the participants. The COSH committee wishes to thank all the speakers for sharing their knowledge and congratulated the quiz winners. The webinar served as a good platform for COSH communication, training, quality enhancement and strategy development for improving COSH in the workplace. The successful webinar would not be possible without the commitment, determination and cooperation of all parties in ensuring this webinar proceeded smoothly and achieved its objectives.

Reported by:
ChM Saiful Fazamil Bin Mohd Ali &
ChM Dr. Vanitha Kunalan, KIMIA Malaysia



# Technical Visit to SIRIM Berhad

On 10th March 2022, a visit to The Cosmetic and Natural Products Section under Industrial Biotechnology Research Centre (IBRC), SIRIM Berhad was made possible by a few registered members of Institut Kimia Malaysia (IKM) led by the Chairperson of the Division of Polymers and Materials Chemistry, Prof. Ts. ChM Dr. Melissa Chan Chin Han. The visit has not only proven to be very educational and enjoyable; it has also become an eye-opener for some who were amazed at how SIRIM Berhad is playing its role in linking the researchers who have successfully extracted active ingredients from natural products to high-end cosmetic products ready to be marketed and sold to customers.

The moisturizing test conducted on the upper hand of Prof. Ts. ChM Dr. Melissa Chan Chin Han, ChM Dr. Faridah Hanim Ab Hanan and ChM Lau Sook Ling suggested that ladies are hard at work when the readings recorded went below 50. Unlike the male counterpart who recorded readings well above 50 when it comes to the skin moisturizing reading; the products produced by SIRIM Berhad to moisturize skin have proven to be effective when all readings went above 50 after its application.

Sample-size product gift packs were presented by SIRIM Berhad to the visitors. In return, IKM, represented by Prof. Ts. ChM Dr. Melissa Chan Chin Han presented IBRC, SIRIM Berhad with an IKM plaque to the Senior Manager Dr. Ahmad Hazri Abdul Rashid. Many thanks to Puan Sarifah Rejab, the Head of Cosmetic and Natural Products Section for introducing the visitors to the laboratories under her section namely the Extraction Process Laboratory; Product Formulation Laboratory; Sensory, Stability and Safety Testing Laboratory and Product Claim Substantiation Laboratory.

During the briefing session, Puan Sarifah Rejab voiced her concern regarding IKM membership application for researchers with master and PhD degrees who may not have Chemistry major as their first degree. “Are they required to complete IKM Refresher Course and enroll for IKM LMIC examination before they could be accepted as registered IKM chemists?” Delightfully, they were informed that when a master or PhD thesis of a researcher comprised of significant portion of work related to chemistry, their application for registered chemists with IKM will be deliberated and scrutinized by IKM Membership Committee.

Reported by:
ChM Dr. Faridah Hanim Ab Hanan
Prof. Ts. ChM Dr. Melissa Chan Chin Han

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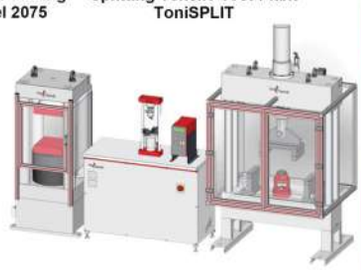

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# 10th Symposium on Best Practices & Innovations in Laboratory Management (10TH BPI-LAB 2021)

The 10th Symposium on Best Practices & Innovations in Laboratory Management 2021 (10th BPI-LAB 2021) was successfully conducted from 24 to 25 March 2022 at the Kuala Lumpur Convention Centre. It is a continuation and a fresh rebranding of the previously held biennial Symposium on Quality, Safety, Environment & Laboratory Informatics (QSEL). This year, 10th BPI-LAB 2021 was jointly organised by Institut Kimia Malaysia (IKM) and Department of Chemistry Malaysia, in collaboration with the Department of Standards Malaysia, Department of Occupational Safety and Health, National Water Research Institute of Malaysia as well as Environmental Preservation & Innovation Centre Sdn Bhd. 10th BPI-LAB 2021 was the first face-to-face event organised by IKM after a 2-year hiatus due to COVID-19 pandemic.

With the theme *Advancing Excellence & Best Practices in Laboratory Operations and Management*, 10th BPI-LAB 2021 focused on the latest development and advances in the field of Green Chemistry & Sustainability, Laboratory Safety & Chemical Hazards, Laboratory Science Education & Quality, Disruptive Technologies and Automation & Digitalisation. BPI-LAB 2021 aimed to help the attendees in keeping up-to-date with the latest development in these areas as the laboratory industry is constantly evolving with new technologies, regulations and ways of working.

The 10th BPI-LAB 2021 organising committee chaired by ChM Dr. Malarvili Ramalingam managed to put together a total of 25 distinguished speakers from various government agencies, academia and industries to present and share their expertise in the five areas during the 2-day event.

The event was officiated by IKM President, Datuk ChM Dr. Soon Ting Kueh. This launch was followed by a plenary session by Prof. ChM Dr. Yang Farina Abdul Aziz (Universiti Kebangsaan Malaysia) who shared her knowledge and personal experience on the topic entitled '*Best Practices in Surviving and Managing Covid-19'*.

On Day-2 of the symposium, Dr. Nagulendran A/L Kangayatkarasu, the Deputy Secretary General, Ministry of Science, Technology and Innovation, gave his keynote address entitled '*Chemistry and Chemist Role is Catalysing STI Agenda in Planetary Health and Achieving SDG Goals – A Policy Perspective'*. In total, over one hundred participants attended the 10th BPI-LAB 2021.

The following tables depict the speakers and their topics according to the five key areas:

| Key Area 1: Laboratory Safety & Chemical Hazards |
|---|
| Growing a Culture of Chemical Security<br>Dr. Hjh. Zalini binti Yunus, Deputy Director General, Science & Technology Research Institute for Defence (STRIDE) |
| OSH Master Plan 2025<br>Puan Ts Hazlina Yon, Director, Department of Safety & Health Malaysia (DOSH) |
| Chemical Hazards in the Laboratory<br>Ms. Chen Bee Chin, Pathology Dept, Former Head Biochemical Laboratory & Safety Officer, HKL |
| Good practices in Fourier-Transform infrared conformity analysis and failure investigation of polymeric products<br>Prof. Ts. ChM. Dr. Chan Chin Han, Faculty of Applied Sciences, Universiti Teknologi MARA |

| Key Area 2: Green Chemistry & Sustainability |
|---|
| Innovations in Laboratory Analysis through Application of Chemosensors and Biosensors Technology<br>Prof. Dato' Dr. Musa Ahmad, Universiti Sains Islam Malaysia (USIM) |
| Waste + Water = Wealth<br>Dr. Pramila Tamunaidu, Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia |
| Green Laboratory Practice in Research<br>Assoc. Prof. Dr. Juan Joon Ching, Institute of Graduate Studies, University of Malaya |
| Innovation Green Chemistry & Sustainability to Service Mankind and Shaping the Future<br>Dr. Lai Fook Chuan, General Manager, Hartalega NGC Sdn. Bhd. |
| Enabling Productivity and Environmental Sustainability in Gas Chromatography and Mass Spectrometry Laboratories<br>Mr. Ian Sik, Technical Support Specialist, Agilent Technologies Malaysia |
| Nanomaterials: Synthesis and Integration Innovative Labs under MOSTI's Rangkaian Makmal Nanoteknologi Kebangsaan (RMNK)<br>Prof. Madya Dr. Ruslinda A. Rahim, Pusat Nanoteknologi Kebangsaan, Kementerian Sains, Teknologi & Inovasi |

| Key Area 3: Laboratory Science Education & Quality |
|---|
| Making Learning Alive: Applications in Ethics and Laboratory Safety Education<br>Dr. Low May Lee, International Medical University |
| Laboratory Science Education – Bridging Schools and Learnings Institutions with Industry, Private and Government Agencies<br>Dr. Gurminder Kaur Sardool Singh, Science Officer, Department of Pathology, HKL |
| Future "Elements" of the Chemical Industry<br>Dr. Tan Shu Ying, Principal Analyst, Malaysian Industry-Government Group for High Technology (MIGHT) |
| Quality and Competency of Accredited Laboratory<br>Pn. Fariza Wan Abdullah, Senior Principal Assistant Director, Department of Standards Malaysia (Standards Malaysia) |
| Halal Science: The Need to Keep Abreast of Recent Technology and Quality Assurance in Halal Analysis<br>Dr. Padillah bt Yahya, Scientific Officer, Industry Tariff Analysis Centre, Department of Chemistry Malaysia (KIMIA Malaysia) |
| Innovations in Forensic Toxicology<br>Dr. Sharmilah Kuppusami, Scientific Officer, Toxicology Division, Department of Chemistry Malaysia (KIMIA Malaysia) |

| Key Area 4: Disruptive Technologies |
|---|
| The Problem May Get Smaller: Microplastics to Nanoplastics<br>Dr. Chin Teen Teen, General Manager, ALS Technichem (M) Sdn. Bhd. |
| Disruptive Technology & Firm Performance<br>Dr. Daljeet Singh Malkeet Singh, Business Director, Acuity Business Solutions |
| ToF: A New Approach for On-Site Analysis of Emerging Contaminant/Pollutant in Air<br>Dr. Tan Yi Hong, Application and Service Engineer / Product Specialist, Tay Scientific Instruments Sdn. Bhd. |

| Key Area 5: Automation & Digitization |
|---|
| IR4.0 and Laboratory Management System<br>Mr. Louis Ooi Shu Geok, Chairman/ Managing Director, Persatuan Makmal Akreditasi Malaysia (PMAM) |
| Where Should It Begin with Lab Automation<br>Mr. Ang Eng Loo, Business Manager, CLMO Technology Sdn Bhd |
| A Graphical User Interface Application for Automated Processing and Chemometrics Analysis of Infrared Spectra<br>Assoc. Prof. Dr. Sim Siong Fong, Universiti Malaysia Sarawak (UNIMAS) |
| Direct Mass Detection Technology, Discover the Power of Knowing Now<br>Ms. Davina Law Stewart, Senior Mass Spectrometry Business Development Specialist, SEA, Waters Analytical Instruments Sdn Bhd |


Parallel to the oral presentations, attendees were also welcomed to visit and observe the exhibition booths set up by agency and technology companies such as Waters Analytical Sdn. Bhd., Tay Scientific Instruments Sdn. Bhd., Agilent Technologies Sales (M) Sdn. Bhd., Orbiting Scientific & Technology Sdn. Bhd. and Standards Malaysia.

The symposium was concluded with a Symposium Banquet held at the end of Day 2. For most of the participants, the 10th BPI-LAB 2021 was the first face-to-face event that they attended since the pandemic started. The organising committee sincerely hope that the participants had a good time catching up with their colleagues and acquaintances.

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# New, innovative GC and GC-MS product portfolio enables greater uptime and efficiency

The innovative gas chromatography (GC) and GC-mass spectrometry (GC-MS) portfolio from Thermo Fisher Scientific is designed to deliver enhanced customer experience, easy adoption and simplified operations.

Analytical testing laboratories across a variety of sectors, including food, environmental, industrial and pharmaceutical can now meet their ever-increasing efficiency and productivity needs with a collection of new gas chromatography and GC-mass spectrometry instruments offering innovative hardware and software updates.

The GC and GC-MS instrument portfolio, including the new **Thermo Scientific™ TRACE™ 1600 Series Gas Chromatograph**, **Thermo Scientific™ AI/AS 1610 Liquid Autosampler**, **Thermo Scientific™ ISQ™ 7610 Single Quadrupole GC-MS** and **Thermo Scientific™ TSQ™ 9610 Triple Quadrupole GC-MS/MS**, now features technological advances that enhance usability and productivity.

Features of the new GC and GC-MS instruments include:

- Unique GC modularity and NeverVent technologies that enable increased instrument uptime by accelerating maintenance operations through user-exchangeable injectors and detectors modules, and the ability to remove MS ion source, filaments and analytical column without breaking the vacuum.
- Wider high-resolution multi-function touch screen, tool-free column connection.
- Illuminated GC oven and autosampler syringe compartment.
- Support from how-to videos directly on the GC touch screen for quick familiarization and adoption.
- Consistent sensitivity and extended linear dynamic range of the new MS detector that enable methods consolidation for maximized sample throughput—a critical need for analytical laboratories performing a high volume of tests.

Introducing the **Thermo Scientific TRACE 1600 Series Gas Chromatograph** which will offer laboratory professionals the advantages of time and space savings. When combined with the **Thermo Scientific AI/AS 1610 Liquid Autosampler**, the system provides reliable automated sample injection to stay ahead of any sample-throughput demand.

The **Thermo Scientific ISQ 7610 Single Quadrupole GC-MS system** is ideal for high-throughput laboratories performing food, environmental, pharma, petrochemical, or forensic toxicology testing. The system offers proven performance and productivity for analytical testing laboratories that need the ultimate confidence of a GC-MS system for trusted and reliable results day after day.

Optimized for high-throughput analytical laboratories, the **Thermo Scientific TSQ 9610 Triple Quadrupole GC-MS/MS system** is the best-in-class system for ultimate sensitivity and quantitation of targeted compounds. This system features productivity tools to maximize sample analysis, minimize downtime, surpass regulatory challenges, and ensure a rapid return on investments.

From left to right:
Thermo Scientific TRACE 1600 Series Gas Chromatograph (GC),
Thermo Scientific ISQ 7610 Single Quadrupole GC-MS system,
Thermo Scientific TSQ 9610 Triple Quadrupole GC-MS/MS system.

# Revolutionizing Quat Pesticide Determination and Quantitation Workflows to Protect Food Supply

Thermo Fisher Scientific is providing laboratories performing food safety analysis with a new ion chromatography tandem mass spectrometry (IC-MS/MS) workflow solution for regulatory compliant, cost-effective and reliable analysis of quaternary ammonium pesticides (Quats). The new **Thermo Scientific™ Dionex™ IonPac™ CS21-Fast-4µm ion exchange column** enables scientists to easily and accurately determine and quantify the four cationic pesticides: diquat, paraquat, mepiquat and chlormequat. When coupled with the Thermo Scientific™ TSQ Altis™ Plus Triple Quadrupole Mass Spectrometer, food safety testing laboratories will benefit from reliable and robust Quat analysis that confidently meets regulatory requirements, while improving laboratory productivity.

**To learn more about these new solutions, please email CMD.APACMARKETING@thermofisher.com**



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## Knowledge Exchange

Thermo Fisher Scientific, the world leader in serving science, is sharing knowledge with chemists, researchers, scientists and other laboratory professionals in Malaysia through virtual experiences, conferences, and forums. Check out these opportunities to connect, learn and exchange knowledge with experts worldwide!

# Ask The Expert – Charged Aerosol Detection Symposium


Throughout the month of June 2022, Thermo Fisher Scientific will host a special Ask The Expert symposium in which our experts will answer questions posed by laboratory professionals from across Asia Pacific and Japan on Charged Aerosol Detection (CAD).

The three live event dates and topics are:
**June 8, 2022 – CAD Basics and Beyond**
**June 15, 2022 – Pharma and biopharma applications**
**June 22, 2022 – Food and beverage applications**

This series of three 'live' events at 13:30 hours Kuala Lumpur time will be available on-demand after each session.

Register today for your 'live' or on-demand webinars at:

# Innovation Summit: Stay ahead with new GC and GCMS technology


We invite laboratory professionals to experience the productivity evolution. Available on-demand, Thermo Fisher Scientific Innovation Summit: Stay Ahead with new GC and GCMS Technology will be beneficial for users in environmental, pharmaceutical and food testing.

Register for the on-demand session at:

# 2022 Global IC Symposium: Take Charge of your IC Analysis


Ion chromatography (IC) is a critical analytical tool on which laboratories rely to analyze charged and polar molecules and provide solutions to some of their most challenging problems.

In this on-demand session hosted by experts, you will:
- Learn to use this powerful separation technique across the IC application spectrum to improve workflows
- Learn about the latest IC applications that are achieving breakthroughs
- Gain valuable insights on how advancements in IC can solve modern challenges

Among the many plenary, presentations and workshops covered in the Symposium are:
- Ion Chromatography for Water Analysis: Yesterday, Today, and Tomorrow
- Ion Chromatography for Pharmaceutical Impurity Analysis
- Application Capabilities of Ion Chromatography in Petroleum Industry
- Column Selection in Ion Chromatography
- Troubleshooting in Ion Chromatography with Thermo Scientific™ Chromeleon™ Chromatography Data Software
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# GC and GC-MS Evolution Enables Greater Uptime and Efficiency



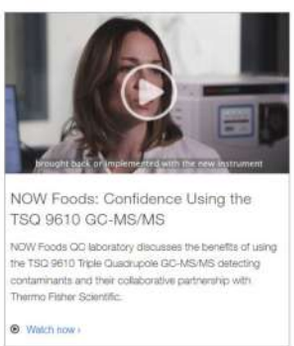
Analytical testing laboratories across a variety of sectors, including food, environmental, industrial and pharma, can now meet their ever-increasing efficiency and productivity needs with a collection of new Thermo Scientific™ gas chromatography (GC) and GC-mass spectrometry (GC-MS) instruments offering innovative hardware and software updates.

A global audience worldwide enjoyed the virtual Innovation Summit on March 8-9, 2022 along with a virtual demo when the new systems were introduced in The Reveal session. The Applied Technology session offered participants the opportunity to attend presentations by users describing enhanced analytical performance and facilitated workflows for Pharma, Food Safety and Environmental laboratories that have helped them to work more efficiently and eliminate nonproductive time.

Through customer feedback, Thermo Fisher Scientific had been able to implement new features that enable increased operational efficiency, ease of use and profitability for both the analytical testing laboratory and research organization.

We invite laboratory professionals in Malaysia to learn more about the use of the new GC and GC-MS technologies.

Scan the QR code below to view a video case study featuring NOW Foods on the benefits of using the TSQ 9610 Triple Quadrupole GC-MS/MS in detecting contaminants.




**Interactive eBook on new GC and GC-MS portfolio**

Enjoy an interactive experience with a virtual tour of the new Thermo Scientific TRACE 1600 Series Gas Chromatograph. The GC can be rotated 360 degrees, with animations triggered by a mouse-click, guiding readers through the many instrument features. There are resources such as a whiteboard video, application notes, whitepaper, product spotlight and technical notes on this new GC.

Additionally, readers can access resources relating to the Thermo Scientific ISQ 7610 Single Quadrupole GC-MS and Thermo Scientific TSQ 9610 Triple Quadrupole GC-MS/MS. These resources include a user video, product videos, case studies, application notes and technical notes.

Visit https://interactive.thermofisher.com/brochure or scan the QR code for the virtual tour and access to the various resources.

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ICPAC KOTA KINABALU 2022

22nd - 27th November 2022

# International Congress on Pure & Applied Chemistry
# Kota Kinabalu, Sabah, Malaysia

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# International Congress on Pure & Applied Chemistry (ICPAC) Kota Kinabalu 2022

**Institut Kimia Malaysia (IKM), together with Universiti Malaysia Sabah (UMS), the Foundation for Interaction between Science and Technology (FIST) Japan and Asia Chem Corporation (ACC) Japan are jointly organising the International Congress on Pure & Applied Chemistry (ICPAC) Kota Kinabalu 2022 from 22nd - 27th November 2022 at the Magellan Sutera Resort, Kota Kinabalu, Sabah, Malaysia. ICPAC KK 2022 is the fifth of a series of major international scientific meeting covering all areas of pure and applied chemistry including specific themed symposia. The theme, "Chemistry & Chemical Innovations for Sustainable Development in Rapidly-Emerging Economies", means that the Congress will focus on advancing chemistry for meeting the UN Sustainable Development Goals 2030. ICPAC KK 2022 will comprise the following General Session and Symposia:**

| |
|---|
| **ICPAC KK 2022 General Session (IGS)** |
| **Symposium on Organic and Biomolecular Chemistry (OBC)** |
| **Symposium on Inorganic and Coordination Chemistry (ICC)** |
| **Symposium on Physical Chemistry and Catalysis (PCC)** |
| **Symposium on Analytical and Environmental Chemistry & Engineering (AEC)** |
| **Symposium on Polymer and Materials Chemistry (PMC)** |
| **International Symposium on Advanced Polymeric Materials 2022 (ISAPM 2022)** |
| **20th Malaysian International Chemistry Congress 2022 (20MICC)** |

## REGISTRATION FEE AND PAYMENT

Those interested to participate or make oral or poster presentation are required to register at the ICPAC KK 2022 website: **https://icpackk2022.org/**. Please complete the REGISTRATION FORM and together with the Registration Fee, submit to the ICPAC KK 2022 Secretariat online. Only those who have paid their Registration Fees are considered as delegates to ICPAC KK 2022.

| Participants | Type of Registration | Early Bird (before or on 31st August 2022) | Regular (from 1st September 2022) |
|---|---|---|---|
| **International Participants** (Non-IKM Members) | International Participants | USD750 | USD850 |
| | Postgraduates Students (Overseas) | USD500 | USD600 |
| **Congress Banquet (additional guest)** | | USD100 | USD100 |
| **Tour (additional guest)** | | USD80 | USD80 |

The deadline for Early-Bird Registration is **31st August 2022**. Registration fee entitles the ICPAC KK 2022 delegates to the following: attendance at all ICPAC KK 2022 scientific sessions, complimentary tour & banquet and all ICPAC KK 2022 documents and materials.

## ACCOMMODATION

**Congress Hotel - The Magellan Sutera Resort**
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## MORE INFORMATION / CONTACT US

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**Telephone:** +603-77283272 / +603-77283858 / +603-77269029 **Fax:** +603-77289909
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# IKM New Members & Membership Upgrading

| NEW MEMBERS (MMIC) | | |
|---|---|---|
| Abdul Razzak Fikri bin Sharkawi<br>M/5983/9581/22 | Low Heng Heng<br>M/6043/9698/22 | Nurul Ain Binti Mohamad<br>M/6022/9660/22 |
| Afifah binti Muhamad Sidik<br>M/5963/9553/22 | Low Joo Yee<br>M/5980/9576/22 | Nurul Athirah binti Ismail, Dr.<br>M/6004/9628/22 |
| Afiq Bin Anwar<br>M/6025/9665/22 | Maizatul Najwa Binti Jajuli, Dr.<br>M/6034/9680/22 | Nurul Atikah bt Mohd Mokhtar, Dr.<br>M/5961/9550/22 |
| Ang Ai Yean<br>M/5996/9602/22 | Maswati binti Basri<br>M/6010/9643/22 | Nurul Najidah binti Mohamed, Dr.<br>*M/5998/9605/22* |
| Ang Jing Jing<br>M/6027/9668/22 | Michele Mejin<br>M/6044/9701/22 | Nurul Syazwani binti Alias<br>*M/5977/9572/22* |
| Anis Tasnim binti Md. Yusof<br>M/6003/9626/22 | Mohammad Qamarruddin bin Rokei<br>M/5989/9590/22 | Phan Tze Pei<br>*M/6013/9648/22* |
| Archina A/P Buthiyappan, Dr.<br>M/5986/9586/22 | Mohd Firkhry Fadhly bin Abdul Ghani<br>M/6047/9707/22 | Pravina A/P Deligannu, Dr.<br>*M/5975/9570/22* |
| Azlan Shah bin Mustafa<br>M/5966/9557/22 | Mohd Rushashraaf bin Ramli<br>M/5972/9563/22 | Rafidah binti Md Yusof<br>*M/5971/9562/22* |
| Bong Woei Ping<br>M/5968/9559/22 | Muhamad Hazim bin Ya<br>M/5978/9574/22 | Rogayah binti Abu Hassan @ Mohamad<br>*M/6046/9704/22* |
| Boon Yih Hui, Dr.<br>M/5969/9560/22 | Muhamad Sharul Nizam Bin Awang<br>M/6037/9688/22 | Seow Lay Jing, Dr.<br>*M/6021/9659/22* |
| Chah Chee Keong, Dr.<br>M/5960/9549/22 | Muhammad Afiq bin Abdullah<br>M/6026/9666/22 | Sharifah Nurfadhlin Afifah binti Syed Azhar<br>*M/5970/9561/22* |
| Chong Jin Mei<br>M/6036/9685/22 | Najwa Izzati Binti Zainal<br>M/5976/9571/22 | Siti Aishah Binti Mohamad Rosidek<br>*M/5973/9567/22* |
| Chong Teck Lean<br>M/6023/9662/22 | Nanthini A/P Selvadurai<br>M/6038/9691/22 | Siti Farhana binti Hisham<br>*M/6033/9679/22* |
| Chong Zan Yang<br>M/6035/9683/22 | Nik Nur Shamiha binti Nik Dzulkefli<br>M/5988/9589/22 | Siti Munirah binti Mohd Faudzi, Dr.<br>*M/5987/9587/22* |
| Cornelius Presley anak Ges<br>M/6032/9677/22 | Nor Afzan binti Kamaludeen<br>M/5991/9593/22 | Siti Nurain binti Md Isa<br>*M/5965/9555/22* |
| Dalily Nabilah binti Lamjin<br>M/6041/9696/22 | Nor Amin bin Hassan<br>M/6012/9645/22 | Sri Ardianti binti Abd Muis<br>*M/5990/9592/22* |
| Dayang Norafizan binti Awang Chee, Dr.<br>M/6007/9635/22 | Nor Amira Binti Marfur<br>M/5993/9596/22 | Suzaimi binti Johari<br>*M/5958/9546/22* |
| Emily S Majanun<br>M/6024/9663/22 | Norfareha binti Abu Bakar<br>M/5964/9554/22 | Syahida Nasuha binti Mohd Bukhari<br>*M/6009/9637/22* |
| Engku Norhafizah binti Engku Ali<br>M/6019/9656/22 | Norilyani Izzati Binti Hasanuddin<br>M/6040/9693/22 | Syaidatul Shafiqah Binti Yusrirohani<br>*M/5984/9583/22* |
| Fathin Nurshafiqa Binti Mohd Zamri<br>M/5962/9551/22 | Norsyahidah binti Mohd Hidzir, Dr.<br>M/6030/9671/22 | Syukriyah binti Ishak, Dr.<br>*M/6028/9669/22* |
| Fazila binti Zakaria<br>M/5999/9608/22 | Nur Ain binti Abu Osman<br>M/6039/9692/22 | Tan Hong Yee, Dr.<br>*M/6016/9653/22* |
| Hemaadevi A/P Paramasivan<br>M/5992/9594/22 | Nur Anis Zafirah binti Zainordin<br>M/6029/9670/22 | Tan Wei Wei<br>*M/6006/9633/22* |
| Irmaizatussyehdany binti Buniyamin<br>M/6018/9655/22 | Nur Athira Ain Binti Rasidi<br>M/6031/9676/22 | Tengku Khamanur Azma binti Tg. Mohd Zamri, Dr. *M/6015/9651/22* |
| Izzuddin Bin Abdul Rahman<br>M/6002/9617/22 | Nur Atikah binti Mohd Saad<br>M/6011/9644/22 | Valerie Cheo Anak Casimir<br>M/5995/9601/22 |
| Jacqueline Jenelee Sijore<br>M/6014/9650/22 | Nur Fatin Azueen binti Rozaini<br>M/6045/9702/22 | Vasagee A/P Elencovan<br>M/5981/9577/22 |
| Khamisah binti Mhd Sarif<br>M/6048/9709/22 | Nur Hidaayah binti Noor Faizal<br>M/5982/9580/22 | Wan Amira Iffah binti Wan Aidi Rahmat<br>M/5979/9575/22 |
| Lim Chu Er<br>M/6042/9697/22 | Nur Hidayah binti Deris<br>M/6008/9636/22 | Wan Norfirdaus bin Wan Salleh<br>M/6005/9631/22 |
| Lim Kuan Hon, Prof. Dr.<br>M/5985/9585/22 | Nur Hidayati binti Jamil<br>M/6017/9654/22 | Wan Nurul Azwaniey Binti Wan Din<br>M/5974/9568/22 |
| Loh Pei Zhen<br>M/5997/9603/22 | Nur Safirah binti Azmi<br>M/5967/9558/22 | Wan Nurul Hidayah binti Yaacob<br>M/6000/9615/22 |

| | | | |
|---|---|---|---|
| Wan Zuraida Wan Mohd Zain, Dr. M/6020/9657/22 | Lim Huey Chen L/3246/9695/22 | Siraj bin Muhamad Ridzuan Nasaruddin L/3212/9619/22 | Rudy Janiuh *M/6063/4686/05/22* |
| Yeoh Zhi Rui M/6001/9616/22 | Lina Khalida binti Norshariffudin L/3211/9618/22 | Siti Nur Aqilah Binti Rosmat L/3248/9700/22 | Siti Mariam binti Supian *M/6052/7383/16/22* |
| Zainul Akmar bin Zakaria, Assoc. Prof. Dr. M/5959/9548/22 | Ling Jem Shan L/3222/9632/22 | Siti Nur Hazirah binti Redzuan *L/3185/9530/22* | Tan Shueai *M/6055/8213/18/22* |
| Zulfadhlin Niami Bin Musa @ Abdul Kader M/6049/9710/22 | Mariam Jamela Binti Ahmad Nasir L/3234/9667/22 | Siti Rabiha Binti Abdul Jalal *L/3210/9614/22* | Umang Stanycie Sakai *M/6062/7316/16/22* |
| Zuliana binti Ahmad M/5994/9600/22 | Mohammad Azri Bin Md Hanafiah L/3223/9634/22 | Siti Salwa Binti Mohamed Salleh *L/3190/9565/22* | **UPGRADE TO FELLOW (FMIC)** |
| **NEW LICENTIATES (LMIC)** | Mohammad Danish Ahnaf bin Faizul Azlan L/3203/9606/22 | Tai Nyok Ling, Dr. *L/3200/9598/22* | Goh Choo Ta, Dr *F/0135/5356/08/22* |
| Anna Cheah L/3221/9630/22 | Muhammad Imran bin Sha'ari L/3232/9658/22 | Tan Boon Hoe *L/3231/9652/22* | Kathiresan a/l V. Sathasivam, Dr. *F/0137/4427/03/22* |
| Arinnie Binti Sahrin L/3230/9649/22 | Muhammad Raimee Bin Serbi L/3237/9675/22 | Tan Hui Ling *L/3245/9690/22* | Mohammad bin Kassim, Prof. Dr. *F/0136/6265/12/22* |
| Charles Rolend Richard L/3217/9624/22 | Muhd Amir Asyraf bin Noh L/3188/9556/22 | Tan Siew Lan *L/3215/9622/22* | |
| Ching Xiao Ting L/3243/9687/22 | Mujibuddin bin Morshidi L/3195/9584/22 | Tan Xiang Han *L/3205/9609/22* | |
| Chua Jia Xin L/3233/9664/22 | Nor Siti Fatimah binti Arif Shah L/3192/9569/22 | Teh Chin Loong *L/3209/9613/22* | |
| Dayangku Siti Nurfariza binti Awang Ahmad Safri L/3184/9407/22 | Norhafiza Binti Sulaiman L/3207/9611/22 | Teoh Jay Kee *L/3225/9639/22* | |
| Drizellia Amy Anak Santuz L/3227/9641/22 | Nur Alisa Binti Aminudin L/3229/9647/22 | Wee Siew Wen *L/3252/9708/22* | |
| Dzulhafiz Said bin Hasbi L/3216/9623/22 | Nur Anissa Binti Zainul Abidin L/3226/9640/22 | Wong Wai Yee *L/3201/9599/22* | |
| Esther Rani Anak Manila L/3250/9705/22 | Nur Athirah Nasuha Binti Mohamad Riza L/3186/9547/22 | Wong Yung Ting *L/3214/9621/22* | |
| Faris Asyraf Bin Alias L/3242/9686/22 | Nur Izzatul Farahin binti Zulkurnain L/3187/9552/22 | Yeo Tze Ying *L/3244/9689/22* | |
| Felicity Valarie Anak Jawan L/3228/9642/22 | Nur Lina Binti Zulkipeli L/3241/9684/22 | Yong Chin Hong *L/3204/9607/22* | |
| Hasreen Khairani binti Salehan L/3196/9588/22 | Nurmelissa Hanani binti Hamidon L/3206/9610/22 | **UPGRADE TO MEMBER (MMIC)** | |
| Hazirah Syahirah Binti Zakria L/3198/9595/22 | Nurul Azima binti Abd Aziz L/3197/9591/22 | Adianah binti Hussin *M/6050/6640/13/22* | |
| Iffah Syazana binti Rusli L/3194/9582/22 | Olivia Livan Emang L/3193/9579/22 | Alan Kong Yong Hian *M/6051/8359/19/22* | |
| Jayalakshmi a/p Rajakumar L/3249/9703/22 | Ooi Yin Yee L/3189/9564/22 | Benedict Anak Samling *M/6059/8380/19/22* | |
| Jennifer Tan Ai Ping L/3238/9678/22 | Puuvinna A/P Jeyasangar L/3235/9672/22 | Boo Su Wei *M/6057/7455/16/22* | |
| Kanagaraj A/L Rajandran L/3202/9604/22 | Rabitah binti Mohamed Hanafiah L/3239/9681/22 | Chow Xin Wei *M/6060/7399/16/22* | |
| Khoo Yee Shu L/3213/9620/22 | Rasvini A/P Asogan L/3236/9674/22 | Gan Wan Han *M/6053/8460/19/22* | |
| Lai Hui Ting L/3220/9629/22 | Saipul Bin Mohd Saleh L/3191/9566/22 | Komathi A/P Govindarajan *M/6061/8338/19/22* | |
| Lau Siau Ting L/3247/9699/22 | Santhya Letchumi a/p Tegaraja L/3218/9625/22 | Mirah binti Jamadi *M/6056/8162/18/22* | |
| Lau Yeh Siang, Dr. L/3199/9597/22 | Seah Haan Shin L/3251/9706/22 | Muhammad Sufi bin Mohd Nor *M/6058/8823/20/22* | |
| Lee Khai Hong L/3240/9682/22 | Shaza Binti Ahmad Nazuki @ Marzuki L/3224/9638/22 | Nik Nor Azrizam bin Nik Norizam *M/6064/7672/17/22* | |
| Lee Shu Zhen L/3208/9612/22 | Shirley Chai Sing Yee L/3219/9627/22 | Norsyamimi binti Che Sulaiman *M/6054/8235/18/22* | |

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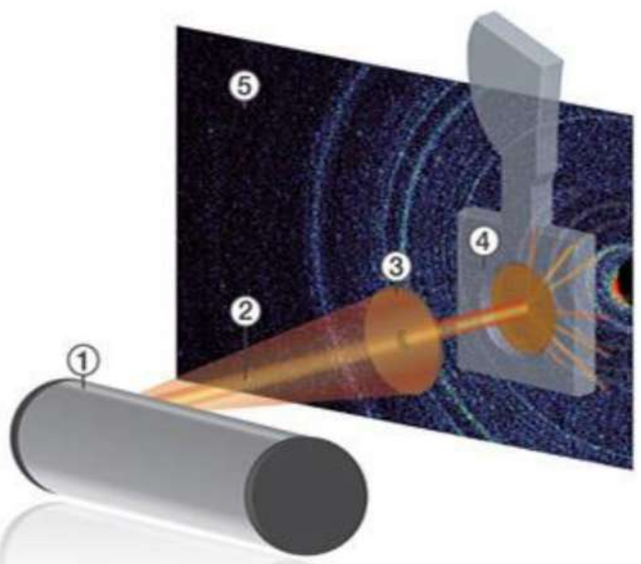


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