ANALYSIS OF PLATINUM GROUP METAL (PGM) TOPIC IN INORGANIC CHEMISTRY COURSE IN INDONESIA

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Received: 07 November 2023. Accepted: 10 Desember 2023. Published: 20 Desember 2023

DOI: 10.30870/educhemia.v8i2.28141

Abstract: Platinum Group Metals (PGM) is one of the topics in elemental chemistry in higher education that is important to teach, considering its major role in various industries. PGM is important in various industrial applications, especially as a catalyst in the automotive, electronics, and environmental technology sectors. This study aims to analyze the topic of Platinum Group Metals (PGM) in elemental chemistry teaching in chemistry education study programs in Indonesia with a focus on its relevance, depth, and pedagogical approach. This study is a qualitative descriptive study with a document analysis approach. Data were collected through analysis of Semester Learning Plan documents for inorganic chemistry courses that contain elemental chemistry topics from several universities in Indonesia. Data were analyzed through the following stages: coding, content analysis, and descriptive qualitative. The study's findings indicate that the discussion of PGM on elemental chemistry is still limited and is taught together with other transition elements. The depth of the material also does not reflect the relevance of PGM in industry, modern technology, and sustainable use. This study recommends increasing elemental chemistry learning by teaching PGM topics in more depth as a provision for students to face challenges in the chemical industry. Interdisciplinary teaching approaches and case studies are also needed to strengthen conceptual understanding and student engagement.

Keywords: Platinum Group Metals (PGM), elemental chemistry, Semester Learning Plan, Inorganic Chemistry Course

Abstrak: Logam Golongan Platina (PGM)merupakan salah satu bahasan dalam kimia unsur diperguruan tinggi yang penting untuk diajarkan mengingat perannya yang besar dalam berbagai industri. PGM memiliki peran penting dalam berbagai aplikasi industri terutama sebagai katalias dalam industri otomotif, elektronik, dan teknologi lingkungan. Penelitian ini bertujuan untuk menganalisis topik Logam Golongan Platina (PGM) dalam pengajaran kimia unsur pada prodi pendidikan kimia di Indonesia dengan fokus pada relevansi, kedalaman, dan pendekatan pedagogisnya. Penelitian ini merupakan penelitian deskriptif kualitatif dengan pendekatan analisis dokumen. Data dikumpulkan melalui analisis dokumen Rencana

Pembelajaran Semester (RPS) mata kuliah bidang kimia aborganik yang memuat bahasan kimia unsur didalamnya dari beberapa universitas di Indonesia. Data di analisis melalui tahapan: pengkodean, analisis isi dan kualitatif deskriptif. Temuan penelitian menunjukkan bahwa pembahasan PGM pada topik kimia unsur masih terbatas dan disampaikan bersamaan dengan unsur transisi lainnya. Kedalaman materi juga belum mencerminkan relevansi PGM dalam industry, teknologi modern, dan penggunaan berkelanjutan. Penelitian ini merekomendasikan adanya peningkatan pada pembelajarn kimia unsur dengan mengajarkan topik PGM yang lebih mendalam sebagai bekal mahasiswa menghadapi tantangan dalam industri kimia. Pendekatan pengajaran interdisipliner dan studi kasus juga diperlukan untuk memperkuat pemahaman konseptual dan keterlibatan siswa.

Kata kunci: Logam Golongan Platina (PGM), Kimia Unsur, Rencana Pembelajaran Semester (RPS), Mata Kuliah Kimia Anorganik

INTRODUCTION

Elemental chemistry is one of the studies in inorganic chemistry. Elemental chemistry discusses the origin, abundance, physical properties, chemical properties, reactivity, extraction, synthesis, and the use of chemical elements and their compounds. Elemental chemistry is an important central area of chemistry and is the basis for studying chemistry further. The discussion of elemental chemistry is filled with various exciting experiments, important and interesting compounds, and discoveries of interesting elements, compounds, and their applications (Greenwood & Earnshaw, 1997). The discussion of elemental chemistry includes all the elements summarized in the periodic system of elements. These elements include alkaline, alkaline earth, groups 13, 14, 15, 16, halogens, noble gases, and transition metals. Transition metals are also divided into outer transition and inner transition, which consist of a set of actinide and lanthanide elements. Elemental chemistry is not a static body of knowledge but continues to develop and is closely related to life.

One of the important topics in elemental chemistry is platinum metal. Platinum is one of the transition metals that have high value and an important role in the industry, such as in the fields of catalysts, electronics, and medicine (Tang et al., 2021; Tang et al., 2023; Yakoumis et al., 2021). The platinum group of metals (PGM) includes six d-block metals from groups 8, 9, and 10 and periods 5 and 6 (Grilli et al., 2023). These metals are ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt) (Hughes et al., 2021; Zhang et al., 2024; Grilli et al., 2023). The chemistry of these elements is similar and is based on the 4d electron shell (Ru, Rh, and Pd) or 5d shell (Os, Ir, and Pt), so it is sufficient to have the collective name platinum metals. The division of PGMs into light PGMs (Ru, Rh, Pd) and heavy PGMs (Os, Ir, and Pt), reflecting atomic numbers, is sometimes used (Hughes et al., 2021).

The PGM elements have silvery and shiny physical properties, so some are used to produce jewelry and gold bullion coins. However, most are used in the chemical industry as catalysts for various reactions. The platinum group of metals is very inert (non-reactive) except for the most extreme reagents, such as aqua regia, a mixture of concentrated hydrochloric and nitric acids. As a result of the lack of chemical reactivity of platinum metals, they are sometimes called noble metals, analogous to noble gases. Another thing that makes platinum metals called noble metals is that PGMs are rare elements in the periodic table (low abundance) (Hughes et al., 2021). The densities of these metals show a strong horizontal relationship: 4d platinum metal has a density of about 12 g.cm-3, while 5d metal is about 21 g.cm-3. The melting point of platinum metals is also high, with values ranging from 1500° to 3000°C (Emsley, 2011).

PGMs are essential for a wide range of end-use applications in consumer and commercial products and industrial processes. The diverse applications of PGMs are critical in the modern era, so understanding the ongoing demand for PGMs and their end-users is essential for managing PGM reserves. Most notably, PGMs find extensive use in a variety of catalytic processes, such as the production of ammonia and ammonium nitrate, as well as in catalytic converters to reduce harmful emissions and pollution from vehicle exhaust systems (Hughes et al., 2021; Zhang et al., 2024; Grilli et al., 2023; Trinh et al., 2020; Saguru et al., 2018; Yakoumis et al., 2021). The use of PGMs in catalytic processes, particularly autocatalysis, had the highest overall demand for PGMs in 2019 (Figure 1) (Hughes et al., 2021). In 2021, global demand for PGMs reached 612 tons, each of which was 229.8 tons of Pt, 346.7 tons of Pd, and 36.1 tons of Rh (Tang et al., 2023). The automotive catalyst industry consumed approximately 32% of the total Pt, 85% of the total Pd, and 90% of the total Rh. To fulfill the large demand, recycling activities of used catalytic converters are carried out to recover Pt, Pd, and Rh metals (Seguru et al., 2018; Tang et al., 2023).

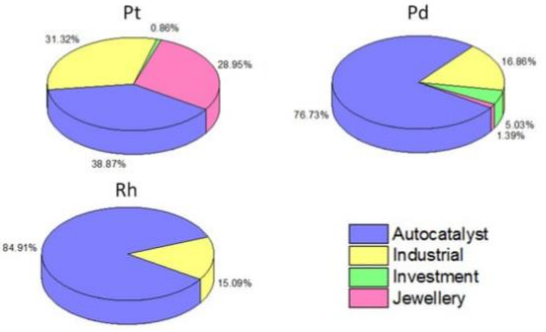

Figure 1. Net demand for Pt, Pd, and Rh from total demand in 2019 (Hughes, et al, 2021)

At the college level, studying the platinum group is very important to provide a deep understanding of the characteristics of PGM elements. Given that PGM are rare elements with unique properties, they are widely used in various fields. Students need to learn the platinum production process, the properties that support its use in various fields, and the analytical methods used to measure platinum content in samples. Understanding platinum is not only theoretical but also through experimental activities in the laboratory, such as experiments in proving the properties of PGM platinum metal extraction experiments. Mastery of these techniques helps students prepare themselves for scientific research involving platinum, especially in materials, catalysis, and environmentally friendly technologies. The increasing global demand for this metal also drives the importance of platinum material in chemistry education in college. From the automotive industry to renewable energy and waste treatment, platinum has many applications that require scientific and technical mastery. Thus, teaching about platinum content analysis not only emphasizes an understanding of its chemical properties but also analytical skills that are relevant to the world of modern research and industry.

Based on the description above, the question arises: How are platinum group metals included in university teaching of elemental chemistry? Is this topic only a minor discussion, or is it the main discussion in elemental chemistry? How relevant is the material taught to the needs of industry or research related to PGM? In order to answer these questions, an analysis of elemental chemistry lectures at various universities in Indonesia was conducted. This study is a new study that has never been done before. In addition, this study is also a preliminary analysis of elemental chemistry lectures to further formulate recommendations for creating innovative lecture designs in teaching elemental chemistry, especially platinum group elements.

METHOD

This study is descriptive qualitative with a document analysis approach (Creswell, 2014). The study focuses on analyzing how platinum group elements are taught in inorganic chemistry courses at various universities in Indonesia. The research sample is the Semester Learning Plan (SLP) document from courses that teach elemental chemistry, which is used in the Chemistry Education study program from various universities in Indonesia. The reason for choosing the SLP from the Chemistry Education study program is because this study is a preliminary study of the main research on developing learning strategies for elemental chemistry lectures for prospective chemistry teacher students. The SLP document was taken from 12 universities spread across Indonesia with a distribution of 1 university in Sulawesi, two universities in Kalimantan, three universities in Sumatra, and six universities in Java. The sampling technique used is random sampling. The research instrument is a document analysis guide containing key indicators to examine and analyze content related to platinum group metals in the SLP, including course names, learning activities, PGM topics, and assessments.

Data collection techniques are carried out by identifying SLP documents according to key indicators. Analysis of learning activities in SLP includes identifying learning strategies or methods and the presence or absence of practical activities related to platinum metal. Analysis of SLP documents will be supported by analysis of teaching materials used in learning. This step is carried out to determine how much platinum metal is discussed in learning.

Data analysis techniques are carried out through the following stages: coding, content analysis, and descriptive qualitative. We code the data collected from SLP and supporting documents based on the main themes, namely, the existence of GPM topics in lectures and the relevance of platinum lectures to industry. After coding, we analyzed the data to see the extent to which the platinum topic is integrated into learning and whether it is in accordance with industry needs or scientific developments. Furthermore, the data obtained will be presented descriptively to describe how platinum is discussed in various university elemental chemistry courses. Data validity is carried out through data triangulation of data obtained from SLP documents with teaching materials used in learning. The aim is to ensure that data interpretation is accurate and relevant.

RESULTS AND DISCUSSION

This section discusses the results of analyzing platinum group metal (PGM) content in elemental chemistry learning in universities. PGM are rare elements with important roles in various industrial and technological applications, making them interesting elements to study in elemental chemistry. Through a review of Semester Learning Plan documents from several universities, it can be evaluated to what extent the topic of PGM is introduced and deepened in the inorganic chemistry or elemental chemistry curriculum. This analysis aims to assess whether the theoretical and applied aspects of PGM, such as physical and chemical properties and its use in catalysis and the automotive industry, have been taught comprehensively at the university level. The results of the analysis of 12 SLP documents for inorganic chemistry courses that contain elemental chemistry are presented in Table 1.

The semester learning plan analyzed in Table 1 is the SLP of the inorganic chemistry course that contains the discussion of elemental chemistry in it. The analysis results show that elemental chemistry is taught with different course names at various universities in Indonesia, including inorganic chemistry II, elemental chemistry, transition metals and complex compounds, chemistry transition and main group element, transition element chemistry, and descriptive inorganic chemistry. The semester load for these courses is an average of two and three credits. This depends on the complexity and breadth of the material.

Topics related to PGM are presented in various ways in various university courses. Several courses, such as chemistry transition and main group element, inorganic chemistry II (C9), and elemental chemistry (C5, C11), do not include a discussion of platinum metals. In the descriptive inorganic chemistry course, the discussion of the platinum metal group is presented in one meeting with a duration of 2 x 50 minutes. Meanwhile, in several other courses, the discussion of PGM is presented together with other transition elements and only in one meeting. Overall, the topic of PGM is presented along with other transition elements in limited portions and is not the main focus. This time limitation indicates that the discussion of the platinum metal group is still general and not in-depth.

The next discussion is related to classroom learning activities that discuss the topic of platinum group metals. The teaching methods used in delivering the topic of platinum metals vary, including discussion, lecture, problem-based learning, presentation, and case method. Discussion is the dominant method used in teaching elemental chemistry. This method allows students to explore elemental chemistry topics, including platinum. The case method is implemented in elemental chemistry courses (C4), which can encourage real case discussions but does not explicitly mention its relationship to platinum. This finding shows that although platinum is taught, not all universities provide space for in-depth and contextual learning about using and analyzing platinum metals in industry or research. In addition, in elemental chemistry laboratory activities, the PGM topic was not involved in practicums.

Meanwhile, in terms of assessment, it was found that most courses that teach elemental chemistry use written tests to measure learning outcomes, including learning outcomes of platinum group metals. Evaluations that only use written tests may be less representative for assessing complex understanding of chemical properties, analytical methods, and real-world applications of platinum. Other evaluation methods, such as laboratory projects or case analysis, would be more effective for this topic.

The discussion of platinum group metals in the analyzed SLP seems to be more theoretical and not focused on direct relevance to industrial applications. As we know, PGM has an important role in the catalyst, automotive, and electronic device industries. More practical and contextual learning about platinum can broaden students' horizons and provide more relevant skills to the world of work. Therefore, in universities, PGM should be taught with a comprehensive and applicable approach, such as a conceptual approach, applied case studies, practicums, sustainable environmental projects, and a system-based approach. A conceptual approach can help students better understand chemical concepts (Dangur et al., 2014), such as platinum group metals' chemical and physical properties and their applications in various fields of life. The topic of platinum metals should also be included in the lab activities. Although platinum is expensive and rare, a well-designed experiment can introduce students to its basic properties. Lab activities can be carried out through platinum metal recovery experiments from industrial or automotive waste. A sustainable environmental project approach can be carried out by discussing environmental and economic issues related to platinum metals, such as availability, extraction from natural resources, and recycling in the context of sustainable chemistry. Studying PGM with a sustainability approach provides scientific insights and an ethical and practical understanding of how science can be used for global sustainability. Meanwhile, a systems-based approach emphasizes the need for systems thinking in teaching chemistry concepts (York & Orgill, 2020). This approach can help students use conceptual understanding and problem-solving skills in discussing global and sustainability issues regarding platinum. With these various approaches, teaching about platinum group metals can provide students with a deep understanding of the importance of these elements, both from a scientific and applied perspective, so that they are ready to face the challenges and opportunities in industry and future technology.

CONCLUSION

The analysis results of Semester Learning Plans (SLP) of various courses from 12 universities spread across Indonesia show that the discussion of platinum group metals in elemental chemistry is still limited. PGM is taught with other transition elements with a very small number of meetings. The depth of the material also does not reflect the importance of platinum in modern industry and technology. In addition, teaching and evaluation methods tend to be theoretical, which does not support students' applied understanding of platinum. Improvements in terms of time allocation, more applied teaching methods, and project-based assessments will be very useful for improving the quality of learning related to platinum group metals in higher education. The findings in this study can be used as a basis for compiling innovative platinum group elemental chemistry lectures that are oriented toward relevance to industry and technology and pay attention to aspects of sustainable chemistry.

Table 1. Analysis Results of 12 Semester Learning Plan (SLP) Documents for Inorganic Chemistry Courses That Contain Elemental Chemistry

SLP Components Analyzed	**Analysis Results of Semester Learning Plan for Each College**											
	C 1	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	**C 8**	**C 9**	**C 10**	**C 11**	**C 12**
Course name	Inorganic Chemistry: Elemental Chemistry	Inorganic Chemistry II	Inorganic Chemistry	Elemental Chemistry	Elemental Chemistry	Descriptive Inorganic Chemistry	Chemistry Transition and Main Group Element	Transition Metals and Complex Compounds	Inorganic Chemistry II	Transition Element Chemistry	Elemental Chemistry	Inorganic Chemistry II
Credit points (CP)	2 CP	3 CP	2 CP	3 CP	3 CP	2 CP	3 CP	2 CP	2 CP	2 CP	3 CP	3 CP
Topics of Platinum Group Metals (PGM)	Taught together with other transition elements in one meeting (2 x @50 minutes)	Taught together with nickel in one meeting (3 x @50 minutes)	Taught together with the transition elements of blocks d and f in one meeting (2 x @50 minutes)	Taught together with other transition elements in one meeting (3 x @50 minutes)	Not taught	Taught in one meeting (2 x @50 minutes)	Not taught	Taught together with other transition elements	Not taught	Taught together with other transition elements	Not taught	Palladium (Pd) is taught together with Nickel (Ni), Platinum (Pt) is taught together with Cobalt (Co) and Copper (Cu) each in one meeting
Course Strategy/Methods	discussion method	Problem Based Learning (PBL)	lecture-based teaching and discussion method	*Case Method*	Writing papers and presentations	lecture-based teaching and discussion method	lecture-based teaching and discussion method	lecture-based teaching and discussion method	lecture-based teaching and discussion method	Team Based Learning (TBL) and discussion method	lecture-based teaching and discussion method	lecture-based teaching and discussion method
Assessment	Written and performance tests	Written tests	Written tests	Written and performance tests	Written and performance tests	Written tests	Written tests	Written tests	Written tests	Written tests	Written tests	Written tests

Information: C = College/University; CP = Credit points

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