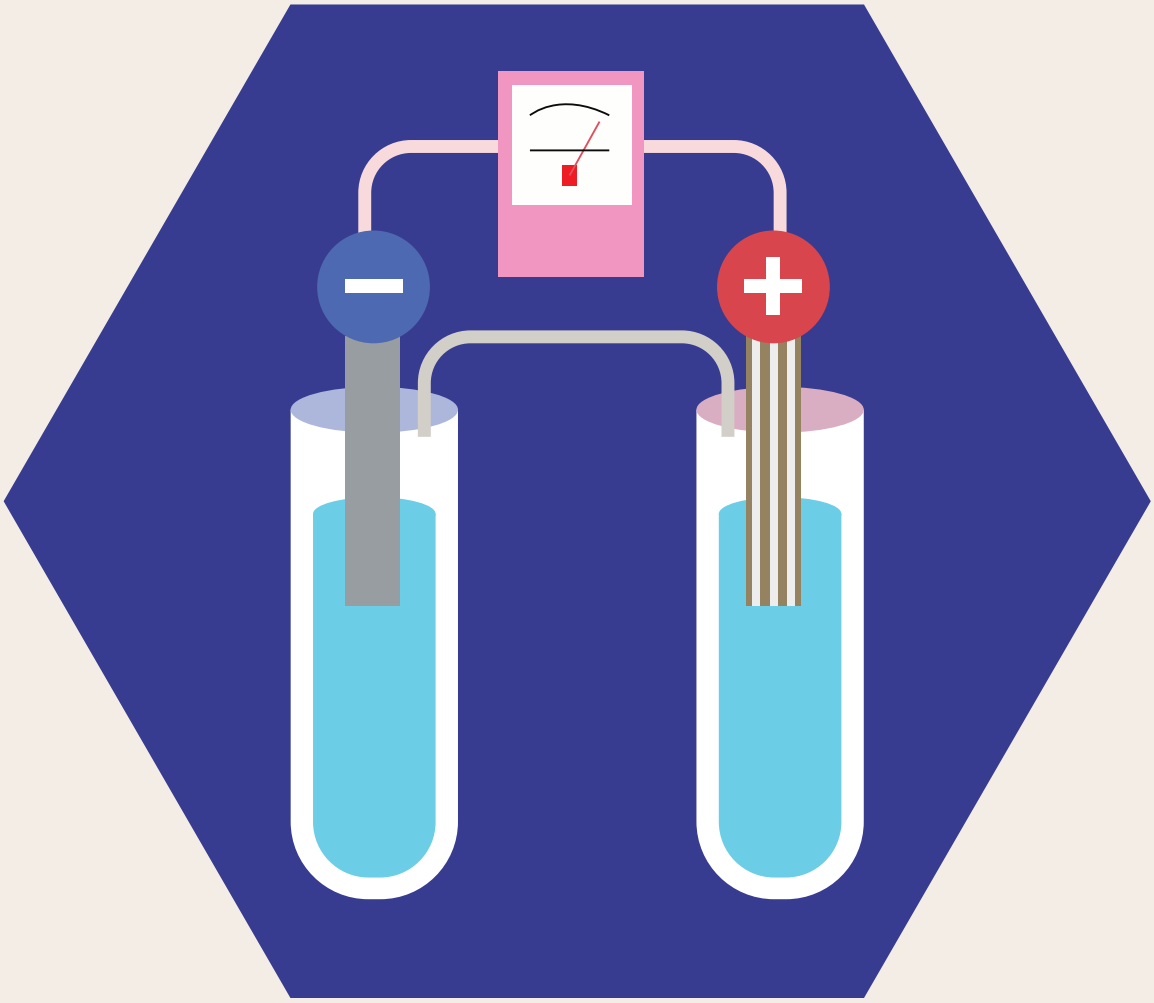
高中自然領域

雙語教學資源手冊

化學科 英語授課用語

A Reference Handbook for Senior High School Bilingual Teachers in the Domain of Natural Sciences (Chemistry): Instructional Language in English

〔高中選修(IV)〕



國立彰化師範大學雙語教學研究中心 發行

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★ 主題一 氧化還原反應與電化學 ★
Oxidation-reduction Reaction and Electrochemistry

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■ 前言 Introduction

本章為氧化還原反應與電化學，接續高一化學（全）的氧化還原反應，更深入的介紹廣義的氧化還原及其應用，包含氧化數的計算，並利用氧化數分別以氧化數法與半反應法平衡氧化還原反應式，期待學生能操作氧化還原滴定的實驗與計量，並運用氧化還原的定義，了解電化電池的原理與構造、法拉第電解定律及電解的應用。在學習這些概念時，我們會用到許多相關的專有名詞和文法，例如：電位差、陽極、陰極、電解質、氧化劑、還原劑等。在課堂中，我們可以利用實驗來引導學生理解這些概念， 並且注意對學生的口語及閱讀能力的培養，以提高學生的跨文化交流能力。

1-1 氧化數
Oxidation State/Number

■ 前言 Introduction

學生於高一化學（全）已學過氧化數的計算，在本小節教師結合舊知識，帶學生了解氧化數的定義並能依據規則計算氧化數，並且應用氧化數的增減判斷氧化還原反應及氧化劑與還原劑。

語言方面，授課中老師可以“electric”、“oxide”等字介紹其他相似字的專有名詞，且學生能運用四則運算的英文來回答氧化數的計算，並介紹氧化反應的定義。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
oxidation state/number	氧化數	electronegativity	電負度
electric charge	電荷數	element	元素態
monatomic ion	單原子離子	hydrogen	氫
metal hydride	金屬氫化物	non-metal hydride	非金屬氫化物
oxide	氧化物	peroxide	過氧化物
superoxide	超氧化物	compound	化合物
polyatomic ion	多原子離子	organic compound	有機化合物

單字	中譯	單字	中譯
oxidation reaction	氧化反應	reduction reaction	還原反應
oxidant	氧化劑	reducing agent	還原劑
concentration	濃度	acid and base value	酸鹼度

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **In general, _____.**
= Generally, _____.

例句：**In general**, the oxidation state/number of oxygen is −2.
一般來說，氧的氧化數為−2。

❷ **_____ is defined as _____.**

例句：An oxidation reaction **is defined as** a reaction in which the oxidation state/number increases.
氧化反應定義為氧化數增加的反應。

❸ **_____ equal(s) _____.**

例句：The sum of all oxidation states/numbers **equals** the total charge carried by the compound.
所有氧化數的總和等於其所帶的電荷數。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出氧化數的定義。

Students can state the definition of oxidation state/number.

二、學生能依據氧化數的規則計算出元素、離子及化合物中的氧化數。

Students can calculate the oxidation states/numbers of elements, ions, and compounds based on the rules of oxidation state/number.

三、學生能透過氧化數的增加與減少判斷氧化還原反應。

Students can use changes in oxidation state/number to identify oxidation-reduction reactions.

四、學生能透過氧化數的增加與減少判斷氧化劑與還原劑。

Students can use changes in oxidation state/number to identify oxidizing and reducing agents.

❧ 例題講解 ☙

例題一

說明：學生能計算化合物中個別元素的氧化數。

Students can calculate the oxidation states/numbers of individual elements in compounds.

Iodine can form many different oxides with varying oxidation states/numbers. One particularly unique compound of iodine and oxygen is known as iodine iodate. Given that the oxidation states/numbers of the iodine atoms in this compound are +3 and +5, which of the following is the chemical formula of iodine iodate?

(A) I_2O_3 (B) I_3O_5 (C) I_3O_6 (D) I_4O_5 **(E) I_4O_9**

碘可以形成很多種氧化物，且可具有不同的氧化數。有一種很特殊的碘與氧的化合物稱為碘酸碘。已知其中碘的氧化數分別為+3 與+5，則下列何者是碘酸碘的化學式？

(A) I_2O_3 (B) I_3O_5 (C) I_3O_6 (D) I_4O_5 **(E) I_4O_9**

（105 年指考 2）

Teacher: The question mentions the compound iodine iodate. What is its chemical formula?

Student: It is IO_3^-.

Teacher: Correct. Now, how can we calculate the oxidation state/number of I in IO_3^-?

Student: The sum of all oxidation states/numbers of the atoms in a polyatomic ion is equal to the charge of the ion. So, assuming the oxidation state/number of I is x, we can list this formula: $x + (-2) \times 3 = -1$. We then can get x = + 5.

Teacher: That's correct. Now that we know that the oxidation state/number is +5, how do we add an iodine ion with an oxidation state/number of +3 to the chemical formula?

Student: Since iodine iodate contains I^{3+} with an oxidation state/number of +3, which needs to pair with three IO_3^- iodate ions each with an oxidation state/number of -1, the chemical formula for iodine iodate is $I(IO_3)_3$.

Teacher: Correct. What can we get after simplifying the formula?

Student: I_4O_9.

Teacher: Yes, E is the correct answer then.

老師： 題目中提到碘酸碘這個化合物，請問各位碘酸根的化學式是什麼？

學生： 是IO_3^-。

老師： 沒錯，接著我們可以如何計算 IO_3^-中 I 的氧化數呢？

學生： 根據多原子離子中，其原子的氧化數總和等於所帶的電荷數，所以我們假設 I 的氧化數為x，可以列出 $x + (-2) \times 3 = -1$這個式子，解出 $x = +5$。

老師： 沒錯，那我們已經知道題目中氧化數為那我們已經知道氧化數為 $+5$ 的碘，那接下來要如何在化學式中加入氧化數為 $+3$的碘離子？

學生： 因為碘酸碘中含有 $+3$的碘 I^{3+}，需要搭配 3 個 -1 的碘酸根 IO_3^-，故需要搭配 3 個 -1 的碘酸根 IO_3^-，故碘酸碘的化學式為 $I(IO_3)_3$ 。

老師： 沒錯，接著我們將化學式整理後可以得碘酸碘的化學式為何？

學生： I_4O_9。

老師： 沒錯，故答案選(E)。

例題二

說明：學生能判斷氧化數的範圍，及了解氧化反應的定義。

Students can determine the range of oxidation states/numbers and understand the definition of oxidation reactions.

Which of the following oxides cannot react with oxygen?

下列氧化物，哪一個無法和氧氣反應？

(A) CO

(B) N_2O

(C) As_2O_3

(D) P_4O_{10}

(E) SO_3

（99 年指考 2）

Teacher: The question asks you to find the oxide that cannot react with oxygen. What type of reaction does this imply that this oxide cannot undergo?

Student: It means it cannot undergo oxidation reactions.

Teacher: That's right. How do we know which compounds cannot undergo oxidation reactions?

Student: When the oxidation state/number has reached its maximum, it can no longer undergo oxidation reactions.

Teacher: Yes, how can we know the range of oxidation states/numbers for each element?

Student: Nonmetals usually have oxidation states/numbers in the range of (valence electrons -8) $\leq$ oxidation state/number $\leq$ group number."

Teacher: Great! So, which option has already reached its maximum oxidation state/number?

Student: S is +6.

Teacher: Correct. Since sulfur is in Group 6A, its oxidation state/number usually ranges from -2 to +6. Therefore, the answer to this question is E.

老師： 題目中要各位找出無法和氧氣反應的氧化物，請問這代表這種氧化物無法再進行何種反應？

學生： 氧化反應。

老師： 沒錯，那我們要怎麼知道哪一種化合物無法再進行氧化反應呢？

學生： 當氧化數已經達到最高時就無法再進行氧化反應。

老師： 對的，那我要怎麼知道各個元素的氧化數範圍呢？

學生： 非金屬通常是 (價電子−8) ≤ 氧化數 ≤ 族數

老師： 太棒了，那哪一個選項的氧化數已經達到最高呢？

學生： S 為 +6。

老師： 對，因為 S 是 6A 族因此他的氧化數通常介於 −2 到 +6 之間，因此這題的答案為 E。

1-2 氧化還原反應式的平衡
Balancing redox equations

■ 前言 Introduction

學生先前已學過使用觀察法及代數法平衡反應式，在本小節教師結合前一節的氧化數觀念，帶領學生了解氧化數法及半反應法平衡等較複雜的氧化還原反應。在授課中教師須提醒學生，平衡化學反應時須注意反應前後是否遵守電荷守恆及質量守恆定律。

語言方面，學生能夠使用四則運算和學習「基於／由於...(定律)」的表達方式，來計算氧化數法和半反應法。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
half-reaction method	半反應法	oxidation number method	氧化數法
the law of charge conservation	電荷守恆	the law of mass conservation	質量守恆定律

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ should follow the law of _____.

例句：Redox reactions **should follow the law of** mass conservation.

氧化還原反應遵守質量守恆定律。

❷ _____ are used in _____ environments _____.

例句：H^+ ions **are used in** acidic **environments** to balance charges.

在酸性環境中利用 H^+ 平衡電荷。

❸ According to ____, _____.

例句：**According to** the law of mass conservation, H_2O is used to balance H and O.

根據質量守恆定律，利用 H_2O 平衡 H、O。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、氧化數法

1. 學生能計算出各原子的氧化數，並且判斷氧化數改變的化合物。
2. 學生能乘上係數使氧化數增減相同。
3. 學生能根據電荷守恆，利用 H^+ 及 OH^- 平衡電荷。
4. 學生能根據質量守恆定律，利用 H_2O 平衡 H、O。

The Oxidation Number Method

1. Students can calculate the oxidation state/number of each atom and identify the compounds whose oxidation states/numbers change.
2. Students can balance the change in oxidation state/number by multiplying coefficients.
3. Students can balance charges using H^+ and OH^- according to the law of charge conservation.
4. Students can balance H and O using H_2O according to the law of mass conservation.

二、半反應法

1. 學生能判斷氧化半反應及還原半反應。
2. 學生能透過氧化數的改變寫出得失電子的數量。
3. 學生能根據電荷守恆，利用 H^+ 及 OH^- 平衡電荷。
4. 學生能根據質量守恆定律，利用 H_2O 平衡 H、O。
5. 學生能乘上係數使電子得失相同。
6. 學生能透過氧化半反應及還原半反應相加消去電子。

The Half-Reaction Method

1. Students can identify oxidation and reduction half-reactions.
2. Students can determine the number of electrons gained or lost based on changes in oxidation state/number.
3. Students can balance charges using H^+ and OH^- based on the law of charge conservation.
4. Students can balance H and O using H_2O based on the law of mass conservation.
5. Students can balance the electrons gained and lost by multiplying coefficients.

例題講解

例題一

說明：學生能計算出各原子的氧化數，並且判斷氧化數改變的化合物。學生能乘上係數使氧化數增減相同。學生能根據質量守恆定律平衡其他係數。

Students can calculate the oxidation states/numbers of each atom and identify the compounds whose oxidation states/numbers change. Students can multiply by coefficients to make the changes in oxidation states/numbers equal. Students can balance the other coefficients according to the law of mass conservation.

Sodium thiosulfate ($Na_2S_2O_3$) can effectively remove residual chlorine from water, and its chemical reaction is shown below: $Na_2S_2O_3 + x\ Cl_2 + y\ H_2O \rightarrow 2NaHSO_4 + z\ HCl$

In the equation, *x*, *y*, and *z* are the coefficients of the balanced reaction. Which of the following statements are correct?

(A) **z = 2x**

(B) **x + y > z**

(C) Cl_2 is oxidized.

(D) The oxidation state/number of S changes from +2 to +4.

(E) This is a self-oxidation-reduction reaction.

硫代硫酸鈉($Na_2S_2O_3$)可有效去除水中殘餘的氯，其化學反應如下所示：

$Na_2S_2O_3 + x\ Cl_2 + y\ H_2O \rightarrow 2NaHSO_4 + z\ HCl$ 式中 x、y 與 z 為該反應式經平衡後的係數。下列哪些敘述正確？

(A) $\boldsymbol{z = 2x}$

(B) $\boldsymbol{x + y > z}$

(C) Cl_2 被氧化

(D) S 的氧化數由+2 變成+4

(E) 此反應為自身氧化還原反應

（102 指考 18）

Teacher: Which atoms undergo redox reactions in the given problem?

Student: The sulfur atoms in sodium thiosulfate and sodium bisulfate, and the chlorine atoms in chlorine and hydrochloric acid.

Teacher: What are their oxidation states/numbers?

Student: The sulfur atoms in sodium thiosulfate and sodium bisulfate are +2 and +6, and the chlorine atoms in chlorine and hydrochloric acid are 0 and -1.

Teacher: In this case, how can we determine which elements and compounds undergo oxidation and which undergo reduction?

Student: Sodium thiosulfate undergoes oxidation because the oxidation state of the sulfur atom increases; chlorine undergoes reduction because the oxidation state of the chlorine atom decreases.

Teacher: Exactly! How much do the oxidation states/numbers increase or decrease in the oxidation and reduction reactions?

Student: Each sulfur atom increases by 4, and each chlorine atom decreases by 1.

Teacher: How do we adjust the coefficients to make the increase and decrease in oxidation states/numbers equal?

Student: $(+4 \times 2) \times 1$及$(-1 \times 2) \times 4$。

Teacher: Very good. Can you tell me the coefficients of $Na_2S_2O_3$, Cl_2 and HCl?

Student: The coefficients of $Na_2S_2O_3$, Cl_2 and HCl are 1, 2, 4 and 8, respectively.

Teacher: And which law should we use to balance the other coefficients?

Student: The law of mass conservation.

Teacher: What is the coefficient of H_2O?

Student: The coefficient of H_2O is 5.

Teacher: Correct! Therefore, the answer to this problem is A and B.

老師： 題目中是那些原子發生氧化還原反應呢？

學生： 是硫代硫酸鈉及硫酸氫鈉的硫原子，及氯和鹽酸的氯原子。

老師： 那他們的氧化數分別為多少呢？

學生： 硫代硫酸鈉及硫酸氫鈉的硫原子為＋2 及＋6，氯和鹽酸的氯原子為 0 及－1。

老師： 很好，因此我們可以判斷哪些元素及化合物發生氧化哪些發生還原？

學生： 硫代硫酸鈉發生氧化，因為硫原子的氧化數增加；氯發生還原，因為氯原子的氧化數減少。

老師： 沒錯！那氧化反應的氧化數增加多少？還原反應的氧化數增加多少？

學生： 每個硫原子氧化數增加 4，每個氯原子氧化數減少 1。

老師： 接著我們要如何調整係數使增加及減少的氧化數相同？

學生： $(+4\times 2)\times 1$及$(-1\times 2)\times 4$。

老師： 很好，請同學告訴老師他們的係數分別為何？

學生： $Na_2S_2O_3$、 Cl_2 及 HCl 的係數分別為 1、2、4 及 8。

老師： 接著我們要使用什麼定律平衡其他係數？

學生： 質量守恆定律。

老師： 那其他化合物的係數為何？

學生： H_2O的係數為 5。

老師： 正確！因此這題的答案為 A 及 B。

例題二

說明：學生能計算氧化數，寫出氧化及還原半反應，並透過消去電子得到全反應。
Students are able to calculate oxidation states/ numbers, write oxidation and reduction half-reactions, and obtain overall reactions by eliminating electrons.

Using the semi-reaction balance method, write the reaction equation for the generation of sulfate ions (SO_4^{2-}) and chromium (III) ions (Cr^{3+}) from sulfite ions (SO_3^{2-}) and dichromate ions ($Cr_2O_7^{2-}$) in an acidic solution.

試使用半反應平衡法，寫出亞硫酸根離子 (SO_3^{2-}) 和二鉻酸根離子($Cr_2O_7^{2-}$) 在酸性溶液中，反應生成硫酸根離子(SO_4^{2-}) 和鉻(III)離子 (Cr^{3+}) 的反應式。

（龍騰版 110 下課本(選修化學 IV)第一章 第 19 頁 例題 1-4）

Teacher: Which two ions participate in the reduction reaction?

Student: $Cr_2O_7^{2-}$ and Cr^{3+}

Teacher: Why?

Student: Because the oxidation state/number of each chromium atom decreases from＋6 to ＋3, and a decrease in oxidation state/number is a reduction reaction.

Teacher: Correct! Let's balance the chromium first to make the coefficient of Cr^{3+} become 2. How do we determine the gain or loss of electrons?

Student: The chromium oxidation state/number in $Cr_2O_7^{2-}$ is＋6, and the chromium oxidation state/number in Cr^{3+} is +3. Therefore, the oxidation state/number of each chromium atom decreases by 3.
This means that the total decrease in the oxidation state/number of chromium in $Cr_2O_7^{2-}$ is 6, which is equivalent to gaining 6 electrons.

Teacher: Very good. Therefore, we can write down $Cr_2O_7^{2-} + 6e^- \rightarrow 2Cr^{3+}$. Now, the question mentions an acidic environment, so which ion do we use to balance the charge?

Student: H^+

Teacher: Now, what is the coefficient of H^+ ions?

Student: Assuming the coefficient of H^+ is x, $-2 + (-1) \times 6 + 1 \times x = (+3) \times 2$, This gives us 14. Therefore, the coefficient of H^+ is 14.

Teacher: We can write $SO_3^{2-} \rightarrow SO_4^{2-} + 2e^- + 2H^+$. Now, according to the law of mass conservation, what do we use to balance H and O? What are the coefficients?

Student: We use H_2O to balance H and O, and the coefficient is 7.

Teacher: Correct! We have completed the reduction half-reaction, which is $Cr_2O_7^{2-} + 6e^- + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O$.
Next, why do SO_3^{2-} and SO_4^{2-} participate in the oxidation reaction?

Student: Because the oxidation state/number of sulfur in SO_3^{2-} is +4, and the oxidation state/number of sulfur in SO_4^{2-} is +6. An increase in oxidation state/number indicates that it is an oxidation reaction.

Teacher: How do we determine the gain of electrons?

Student: The oxidation state/number of sulfur increases from +4 to +6, which is an increase of 2, which means that sulfur loses 2 electrons.

Teacher: Good, so we can get $SO_3^{2-} \rightarrow SO_4^{2-} + 2e^-$. How do we balance the charge?

Student: We add $2H^+$ on the right side of the arrow.

Teacher: We can write $SO_3^{2-} \rightarrow SO_4^{2-} + 2e^- + 2H^+$.
Now, according to the law of mass conservation, we use H_2O to balance H and O, and what are the coefficients?

Student: The coefficient is 1.

Teacher: Correct! We have completed the oxidation half-reaction, which is $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2e^- + 2H^+$. How do we use the oxidation and reduction half-reactions to obtain the overall reaction?

Student: We need to make the number of electrons gained and the number of electrons lost equal in the oxidation and reduction reactions. In the reduction half-reaction, we gained $6e^-$, and in the oxidation half-reaction, we lost $2e^-$. Therefore, (reduction half-reaction) ×1+(oxidation half-reaction) × 3=overall reaction.

Teacher: Excellent! After canceling out the electrons, we obtain the overall reaction, which is $Cr_2O_7^{2-} + 3SO_3^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$.

老師： 請問哪兩個離子參與還原反應？

學生： $Cr_2O_7^{2-}$ 及 Cr^{3+}。

老師： 為什麼？

學生： 因為每個鉻原子的氧化數由＋6 變成＋3，氧化數減少就是還原反應。

老師： 沒錯！那我們先將鉻的數量平衡，使 Cr^{3+}的係數變成 2，要如何判斷得失多少個電子？

學生： $Cr_2O_7^{2-}$ 的鉻氧化數為＋6，Cr^{3+} 的鉻氧化數為＋3，因此每個鉻的氧化數減少 3，因此$Cr_2O_7^{2-}$中鉻氧化數總共減少 6，即為得到 6 個電子。

老師：很好，因此我們可以寫出 $Cr_2O_7^{2-} + 6e^- \rightarrow 2Cr^{3+}$。
接下來題目中有提及在酸性環境中，因此我們要使用哪一個離子來平衡電荷？

學生：H^+。

老師：那麼請同學計算一下，H^+的係數應該為多少？

學生：假設H^+的係數為x，$-2 + (-1) \times 6 + 1 \times x = (+3) \times 2$，解出 $x = 14$，因此 H^+的係數為 14。

老師：我們可以寫出 $Cr_2O_7^{2-} + 6e^- + 14H^+ \rightarrow 2Cr^{3+}$，接下來我們根據質量守恆定律，利用什麼來平衡 H、O？係數是多少呢？

學生：我們要用 H_2O來平衡，係數為 7。

老師：正確！我們完成了還原半反應，$Cr_2O_7^{2-} + 6e^- + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O$。接著$SO_3^{2-}$和$SO_4^{2-}$參與氧化反應，為什麼？

學生：因為SO_3^{2-}中硫的氧化數為＋4，SO_4^{2-}中硫的氧化數為＋6，氧化數增加就是氧化反應。

老師：要如何判斷得失多少個電子？

學生：硫的氧化數由＋4 變成＋6，氧化數增加 2，即為失去 2 個電子。

老師：好，因此我們可以寫出 $SO_3^{2-} \rightarrow SO_4^{2-} + 2e^-$，接著我們要如何平衡電荷？

學生：於箭頭右側補上 $2H^+$。

老師：我們可以寫出$SO_3^{2-} \rightarrow SO_4^{2-} + 2e^- + 2H^+$，我們根據質量守恆定律要用$H_2O$來平衡 H、O，係數是多少呢？

學生：係數為 1。

老師：正確！因此完成氧化半反應 $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2e^- + 2H^+$。接下來我們要如何利用氧化半反應與還原半反應求得全反應？

學生：需要使氧化還原中得失電子的個數相同，還原半反應中得到 $6e^-$，氧化半反應中失去$2e^-$，因此 (還原半反應)×1+(氧化半反應)×3=全反應 。

老師：太棒了！消去電子後我們就可以得到全反應為
$Cr_2O_7^{2-} + 3SO_3^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$。

1-3 氧化還原滴定 Oxidation Number

■ 前言 Introduction

先前學生已學過酸鹼滴定，因此對於當量點與滴定終點有一定的了解，根據先前學過的觀念講解氧化還原滴定的定義及原理，以及舉出常見的氧化還原滴定，其中碘滴定分為直接滴定與間接滴定。在授課中教師須提醒學生，若滴定物或被滴定物在反應前後顏色有明顯變化，則不需額外添加指示劑。

語言方面，學生能夠透過英文句型的學習來表述化學反應結合或達到滴定終點時的變化，也透過英文單字 "equivalence" 和 "end" 在日常的英文用法，協助學生更便於理解相關詞彙的化學差異。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
oxidation-reduction titration	氧化還原滴定	molarity	體積莫耳濃度
volume	體積	number of moles	莫耳數
equivalence point	當量點	end point	滴定終點
indicator	指示劑	starch	澱粉
iodometry	碘滴定法	coordination complex	錯合物
direct titration	直接滴定法	indirect/back titration	間接/反滴定法

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ If _____, it will be called_____.

例句：**If** oxidant and reductant reach a complete reaction, **it will be called** an equivalence point.
當氧化劑與還原劑完全反應時稱為當量點。

❷ When _____, it will produce _____.

例句：**When** iodine reacts with starch**, it will produce** a blue complex.
碘與澱粉作用會生成藍色的錯合物。

❸ When_____, _____ change(s) into _____.

例句：**When** it reaches to the endpoint of the titration, the color of the solution **changes into** light purple.
達滴定終點時，溶液顏色由無色變為淡紫色。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出當量點與滴定終點的定義。

Students can state the definitions of the equivalence point and the endpoint of a titration.

二、學生能利用$C_{ox} \times V_{ox} \times n_{ox} = C_{red} \times V_{red} \times n_{red}$計算出未知濃度的氧化劑或還原劑。

Students can calculate the unknown concentration of an oxidizing agent or reducing agent, using the formula $C_{ox} \times V_{ox} \times n_{ox} = C_{red} \times V_{red} \times n_{red}$.

三、學生能判斷氧化還原滴定的滴定終點。

Students can determine the endpoint of a redox titration.

四、學生能區別碘滴定中的直接滴定法與間接滴定法。

Students can distinguish between direct and indirect titration methods in iodometry.

∞ 例題講解 ∞

例題一

說明：學生能說明氧化還原滴定的過程與判斷氧化劑、還原劑及滴定終點。

Students can explain the process of oxidation-reduction titration and identify the oxidizing agent, reducing agent, and endpoint of the titration.

In a redox titration experiment, the concentration of potassium permanganate solution is first standardized with sodium oxalate, and then the content of ferrous ions in the unknown sample is determined using the standardized potassium permanganate solution. Which of the following statements regarding the experiment is/are correct?

(A) The mass of sodium oxalate must be accurately weighed to determine its precise mole number.

(B) The standardized potassium permanganate solution must be stored in a brown bottle and kept away from light.

(C) In the standardization process, potassium permanganate is the reducing agent and sodium oxalate is the oxidizing agent.

(D) When standardizing the potassium permanganate solution, a single standardization is sufficient to accurately determine its concentration, and there is no need to perform multiple standardizations and average the results.

(E) The endpoint of the titration is reached when the light purple color of the solution persists after adding the standardized potassium permanganate solution to the sample containing ferrous ions.

在氧化還原滴定實驗中，先用草酸鈉標定過錳酸鉀溶液的濃度，再以標定後的過錳酸鉀溶液測定未知試樣中亞鐵離子的含量。下列有關該實驗的敘述，哪些正確？

(A) 須精稱乾燥草酸鈉的質量，以得知其準確的莫耳數。

(B) 標定後的過錳酸鉀溶液，必須儲存於褐色瓶中，且避免光照。

(C) 標定過程中，過錳酸鉀為還原劑，草酸鈉為氧化劑。

(D) 在標定過錳酸鉀溶液時，標定一次即可精確求得其濃度，無須進行多次再求平均的方式。

(E) 以標定後的過錳酸鉀溶液滴定待測樣品中的亞鐵離子，至溶液淡紫色不消失，即為滴定終點。

（105 年指考 25）

Teacher: The question states that sodium oxalate is the standard substance used to titrate potassium permanganate. Is it necessary to accurately weigh sodium oxalate?

Student: Yes, it is necessary to accurately weigh it to obtain to a known number of moles to standardize potassium permanganate and to determine its concentration.

Teacher: Correct! Therefore, option (A) is the right answer.
What kind of container should the titrated potassium permanganate be stored in?

Student: It should be stored in a dark container to prevent decomposition due to light exposure, which could change its concentration.

Teacher: Correct. Therefore, option (B) is also correct.
Which substance is the oxidant and which is the reductant during the titration process?

Student: After titration, potassium permanganate is reduced to manganese ions with the oxidation state/number changing from +7 to +2. It is the oxidant. Sodium oxalate is oxidized to carbon dioxide, with the oxidation state/number changing from +3 to +4, acting as the reductant.

Teacher: Therefore, option (C) is incorrect.
Do we need to perform multiple experiments and take the average during standardization, just as we do during titration?

Student: Yes, this can help to reduce experimental errors.

Teacher: Excellent! Therefore, option (D) is incorrect.
How do we determine the end point during titration?

Student: MnO_4^- titrates Fe^{2+} to get Mn^{2+} and Fe^{3+}. When MnO_4^- is no longer reduced to Mn^{2+}, the solution has reached the end point. At this point, the solution turns light purple.

Teacher: Well done! In this case, the correct answers for this question are (A), (B), and (E).

老師： 題目中敘述以草酸鈉當成標準品標定過錳酸鉀，草酸鈉是否須精秤？

學生： 是，需精秤後得到已知的莫耳數，在標定過錳酸鉀，確定過錳酸鉀的濃度。

老師： 沒錯！因此(A)選項是正確的。那標定後的過錳酸鉀是否需置於哪一種容器中？

學生： 需放於深色容器中，避免過錳酸鉀經光照後分解，改變濃度。

老師： 對，因此(B)選項也是正確的。標定過程中氧化劑與還原劑分別為哪一個？

學生： 標定後，過錳酸鉀變為二價的錳離子，氧化數由＋7 變為＋2 為氧化劑；草酸鈉變為二氧化碳，氧化數由＋3 變為＋4 為還原劑。

老師： 因此(C)選項是錯誤的，那我們在標定時也需要跟滴定時一樣，需實驗多次取平均嗎？

學生： 是的，這樣才可以減少實驗誤差。

老師： 很好！因此(D)選項是錯誤的，那我們要如何判斷是否到達滴定終點？

學生： MnO_4^-滴定Fe^{2+}，可得Mn^{2+}及Fe^{3+}，因此當MnO_4^-不會再被還原成Mn^{2+}時，就代表溶液達滴定終點，此時溶液變為淡紫色。

老師： 太棒了！因此這一題的答案為(A)(B)(E)。

例題二

說明：學生能判斷氧化還原滴定的氧化劑、還原劑及滴定終點，並計算出未知濃度的氧化劑或還原劑。

Students can identify the oxidizing agent, reducing agent, and endpoint of oxidation-reduction titration, and calculate the concentration of an unknown oxidizing or reducing agent.

Dissolve a commercially available vitamin C tablet (molecular formula $C_6H_{12}O_6$, molecular weight = 176) in water to prepare a 100 mL solution. Take 20 mL of this solution and place it in an Erlenmeyer flask, then add a suitable amount of starch solution as an indicator. Twelve mL of 0.10 M iodine solution is required to reach the titration endpoint. The chemical reaction between vitamin C and iodine is as follows:

$$C_6H_{12}O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

Which of the following statements regarding the experiment is/are correct?

(A) The pH of the solution in the Erlenmeyer flask increases at the titration endpoint.

(B) In the reaction, iodine acts as the oxidizing agent.

(C) In the reaction, each mole of vitamin C molecules releases 2 moles of electrons.

(D) When the blue color no longer disappears, it indicates that the solution in the Erlenmeyer flask contains a slight excess of iodine.

(E) This commercially available vitamin C tablet contains approximately 500 mg of vitamin C.

將一顆市售維他命 C（分子式 $C_6H_{12}O_6$ ，分子量＝176）加水使其完全溶解，配製成 100 mL 溶液。取此溶液 20 mL 置入一錐形瓶中，加入適量的澱粉液作為指示劑，需用 12 mL 的 0.10 M 碘液滴定，達到滴定終點，維他命 C 與碘的化學反應式如下：

$$C_6H_{12}O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

下列敘述，哪些正確？

(A) 滴定終點時錐形瓶內溶液的 pH 值上升。

(B) 反應中，碘為氧化劑。

(C) 反應中每莫耳維他命 C 分子釋出 2 莫耳電子。

(D) 當藍色不再消失，表示錐形瓶中溶液含有少許過量的碘。

(E) 此顆市售維他命 C 中約含有 500 mg 的維他命 C。

Teacher: How can we determine whether the pH value increases or decreases after titration?

Student: The pH value decreases because H^+ is generated after the reaction.

Teacher: Correct! Therefore, option (A) is wrong.
What are the oxidizing and reducing agents during the titration process?

Student: The average oxidation state/number of carbon in vitamin C changes from 0 to +1, indicating that it is the reducing agent. The oxidation state/number of iodine changes from 0 to -1, indicating that it is the oxidizing agent.

Teacher: Option (B) is correct.
How can we determine how many electrons each mole of vitamin C molecules gains or loses during the process?

Student: We can tell that iodine gains two moles of electrons when it becomes $2I^-$. The number of electrons gained and lost is the same in redox reactions. Because the coefficient of vitamin C is 1, we know that 1 mole of vitamin C loses 2 moles of electrons.

Teacher: Correct! Therefore, option (C) is correct.
How can we determine the endpoint of the titration?

Student: I_2 is titrated with $C_6H_{12}O_6$ to produce $C_6H_6O_6$ and I^- in the solution. Starch is added to the solution as an indicator. When I_2 is no longer reduced to I^-, the solution has reached the endpoint and turns blue.

Teacher: Very good! Therefore, option (D) is correct.
How can we determine the amount of vitamin C in a commercially available vitamin C tablet?

Student: Assuming there is x grams of vitamin C,

$$C_{ox} \times V_{ox} \times n_{ox} = C_{red} \times V_{red} \times n_{red}$$

$$\Rightarrow \frac{\frac{x}{176}}{100 \times 10^{-3}} \times 50 \times 10^{-3} \times 2 = 0.1 \times 12 \times 10^{-3} \times 2$$

$$\Rightarrow x = 1.056 \ \ g = 1056 \ \ mg$$

Teacher: Correct! Therefore, option (E) is wrong.

老師：　我們可以如何判斷滴定後的 pH 值上升或下降？

學生：　pH 值下降，因為反應後生成H^+。

老師：　答對了！因此(A)選項是錯的。那請問滴定的過程中氧化劑和還原劑分別為何者？

學生：　維他命 C 中碳的平均氧化數由 0 變成＋1，氧化數增加當還原劑；碘的氧化數由 0 變成－1，氧化數減少當氧化劑。

老師：　(B)選項是正確的。那我們要如何得知每莫耳維他命 C 分子得到或失去多少電子？

學生：　可以從I_2變成$2I^-$得知碘得到 2 mol 的電子，氧化還原中得失的電子數相同，又因為維他命 C 的係數為 1，因此 1 mol 的維他命 C 失去 2 mol 的電子。

老師：　沒錯！因此(C)選項是正確的。那我們該如何判斷滴定終點？

學生：　I_2 滴定 $C_6H_{12}O_6$，可 得$C_6H_6O_6$ 及 I^-，溶液中加入澱粉當成指示劑，因此當 I_2 不會再被還原成I^-時，就代表溶液達滴定終點，此時溶液變為藍色。

老師：　很好！所以(D)選項是正確的。接下來我們可以如何知道一顆市售的維他命 C 中含有多少維他命 C？

學生：　假設 維他命 C x 克

$$C_{ox} \times V_{ox} \times n_{ox} = C_{red} \times V_{red} \times n_{red}$$

$$\Rightarrow \frac{\frac{x}{176}}{100 \times 10^{-3}} \times 50 \times 10^{-3} \times 2 = 0.1 \times 12 \times 10^{-3} \times 2$$

$$\Rightarrow x = 1.056 \ \ g = 1056 \ \ mg$$

老師：　沒錯！所以(E)選項是錯誤的。

1-4 電化電池與電池電壓
Electrochemical Cells and Battery Voltage

■ 前言 Introduction

在本小節教師帶學生了解電化電池的原理與基本構造，認識標準還原電位，能透過氧化及還原電位計算電池的電壓，了解各電池的組成與反應並比較其優缺點，在授課中教師須提醒學生，要清楚知道陰陽極與正負極的定義。

語言方面，授課中老師透過「轉變／移動」的句型幫助學生理解電子流動的方向和化學能與電能之間的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
spontaneous	自發性的	nonspontaneous	非自發性的
chemical energy	化學能	electric energy	電能
electrode	電極	electrochemical cell	電化電池 (化學電池)
electrolyte	電解液	salt bridge	鹽橋
anode	陽極	cathode	陰極
positive electrode	正極	negative electrode	負極
half cell	半電池	electric current	電流
external circuit	外電路	internal circuit	內電路
electric potential	電位	voltage	電壓

單字	中譯	單字	中譯
electromotive force	電動勢	standard hydrogen electrode	標準氫電極
primary cell	一次電池	secondary cell	二次電池
fuel cell	燃料電池	dry cell	乾電池
alkaline battery	鹼性電池	lead storage battery	鉛蓄電池
lithium battery	鋰電池		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ consist(s) of _____.

例句：The oxidation-reduction cell **consists of** a zinc plate and a zinc sulfate solution.
氧化還原電池由鋅片與硫酸鋅溶液組成。

❷ _____ move from ____ to ____.

例句：Electrons **move from** the anode **to** the cathode through an external circuit.
電子經由外電路由陽極移向陰極。

❸ _____ transform(s) _____ into _____.

例句：The device that **transforms** chemical energy **into** electrical energy by spontaneous oxidation-reduction is called an electrochemical cell.
利用自發氧化還原，將化學能轉換成電能的裝置，稱為電化電池。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能判斷電池中陰、陽極及正負極。

Students can identify the anode, cathode, positive, and negative electrodes in a battery.

二、學生能寫出電池表示法。

Students can write the battery notation.

三、學生能歸納半電池的特性。

Students can summarize the characteristics of half-cells.

四、學生能透過氧化及還原電位計算電池的電壓。

Students can calculate the voltage of a battery using oxidation-reduction potentials.

五、學生能利用電位判斷氧化劑與還原劑的強弱、電池的兩極與反應是否自發。

Students can use potentials to determine the strength of the oxidizing agent and reducing agent, the electrodes of a battery, and whether the reaction are spontaneous.

六、學生能說出各電池的組成與反應並比較其優缺點。

Students can describe the composition and reactions of various batteries and compare their advantages and disadvantages.

∞ 例題講解 ∞

例題一

說明：學生能判斷電池中陰、陽極及正負極與電池表示法，並能透過氧化及還原電位計算電池的電壓。

Students are able to determine the cathode, anode, positive and negative terminals, and the cell notation of a battery, and can calculate the voltage of the battery using oxidation and reduction potentials.

A zinc-silver battery can be represented in the following way:
$Zn(s)|Zn^{2+}(aq)||Ag^{+}(aq)|Ag(s)$, where "||" represents a salt bridge. Which of the following statements about the zinc-silver battery is/are correct?

(A) The overall reaction of this battery is $Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$.

(B) During discharge, electrons flow from the zinc electrode to the silver electrode through the external circuit.

(C) In the expression of this battery, the left side represents the cathode.

(D) Ag^{+} gains electrons to produce Ag, so the silver half-cell is represented as $Ag^{+}(aq)|Ag(s)$

(E) The voltage of this battery can be directly obtained by subtracting the reduction potential of zinc from twice the reduction potential of silver.

鋅銀電池可用下列方式表示： $Zn(s)|Zn^{2+}(aq)||Ag^{+}(aq)|Ag(s)$，其中「||」代表鹽橋。下列關於鋅銀電池的敘述，哪些正確？

(A) 此電池的全反應為$Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$ 。

(B) 電池放電時，電子由鋅極經外電路流向銀極。

(C) 此一電池的表示式中，左側為陰極。

(D) Ag^{+} 得到電子產生 Ag，所以銀半電池表示為 $Ag^{+}(aq)|Ag(s)$ 。

(E) 此一電池的電壓可以直接用兩倍銀的還原電位減去鋅的還原電位而得。

（104 年指考 21)

Teacher: How can we determine which metal is the cathode and which is the anode in a zinc-silver battery?

Student: Zinc is more prone to losing electrons, so zinc is the anode, and silver is the cathode.

Teacher: Correct. So how do we write the overall reaction of the zinc-silver battery?

Student: $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$, zinc undergoes oxidation and becomes ions, while silver ions undergo reduction and become silver.

Teacher: Very good, so option (A) is correct.
Now, how do electrons flow during discharge in a zinc-silver battery?

Student: Zinc undergoes oxidation and loses electrons, and silver ions undergo reduction and gain electrons. Electrons flow from the zinc electrode to the silver electrode through the external circuit.

Teacher: That's right! So, option (B) is correct.
How can we interpret battery notations?

Student: In battery notation, "||" represents a salt bridge, "|" represents an interface, the left side is the anode, the right side is the cathode, and it's written as "Anode |Anode ions ||Cathode ions |Cathode."

Teacher: So, option (C) is incorrect. How do we write the half-cell notations?

Student: Zn loses electrons to form Zn^{2+}, so the zinc half-cell notation is $Zn(s)|Zn^{2+}(aq)$. Ag^+gains electrons to form Ag, so the silver half-cell notation is $Ag^+(aq)|Ag(s)$.

Teacher: Excellent! Hence, option (D) is correct.
How do we use reduction potentials to calculate the voltage of the zinc-silver battery?

Student: Battery voltage = Reduction potential of silver - Reduction potential of zinc.

Teacher: So, option (E) is incorrect. Therefore, (A)(B)(D) are correct statements.

老師： 我們可以如何得知在鋅銀電池中陰極與陽極分別為哪一個金屬？

學生： 鋅較容易失去電子，因此鋅為陽極，銀為陰極。

老師： 沒錯，所以我們要如何寫出鋅銀電池的全反應。

學生： $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$，鋅發生氧化變成離子，銀離子發生還原變成銀。

老師： 很好，所以(A)選項是正確的。那鋅銀電池放電時電子是怎麼流動的？

學生： 鋅會發生氧化失去電子，銀離子發生還原得到電子，電子經由外電路從鋅極流向銀極。

老師： 對的！所以(B)選項是正確的。那我們可以如何判斷電池表示法？

學生： 電池表示法中由||表示鹽橋，|當成界面，左側為陽極，右側為陰極，陽極|陽極離子 ‖ 陰極離子|陰極。

老師： 所以(C)選項是錯誤的。那我們要如何寫出半電池表示法？

學生： Zn失去電子產生Zn^{2+}，鋅半電池表示為 $Zn(s)|Zn^{2+}(aq)$

Ag^{+}得到電子產生Ag ，銀半電池表示為 $Ag^{+}(aq)|Ag(s)$

老師： 很好！因此(D)選項是正確的。我們如何用還原電位計算鋅銀電池的電壓？

學生： 電池電壓=銀的還原電位−鋅的還原電位。

老師： 所以(E)選項是錯誤的。因此答案為(A)(B)(D)。

例題二

說明：學生能利用電位判斷氧化劑與還原劑的強弱。

Students can use potentials to determine the strength of oxidizing and reducing agents.

At 25°C, the standard reduction potentials for the following three half-reactions are given as follows:

$Al^{3+}(aq) + 3e^{-} \rightarrow Al(s)$ $\quad E° = -1.66V$

$I_2(s) + 2e^{-} \rightarrow 2I^{-}(aq)$ $\quad E° = +0.54V$

$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ $\quad E° = +1.51V$

Under standard conditions, which of the following is the strongest reducing agent?

(A) $Al^{3+}(aq)$ **(B) $\boldsymbol{Al(s)}$** (C) $I_2(s)$

(D) $I^{-}(aq)$ (E) $MnO_4^{-}(aq)$

25°C時，下列三個半反應的標準還原電位如下：

$Al^{3+}(aq) + 3e^{-} \rightarrow Al(s)$ $\quad E° = -1.66V$

$I_2(s) + 2e^{-} \rightarrow 2I^{-}(aq)$ $\quad E° = +0.54V$

$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ $\quad E° = +1.51V$

則在標準狀態下，下列何者為最強的還原劑？

(A) $Al^{3+}(aq)$ **(B) $\boldsymbol{Al(s)}$** (C) $I_2(s)$

(D) $I^{-}(aq)$ (E) $MnO_4^{-}(aq)$

（107 指考 14）

Teacher: What is the definition of a reducing agent?

Student: A reducing agent causes others to undergo reduction while it itself undergoes oxidation.

Teacher: So, which substances in the question are serving as reducing agents?

Student: $Al, I^{-}\ and\ Mn^{2+}$.

Teacher: Correct. Now, how do we determine the strength of reducing agents?

Student: The greater the oxidation potential, the stronger the reducing agent.

Teacher: What are the oxidation potentials of these substances?

Student: $Al(1.66V) > I^{-}(-0.54V) > Mn^{2+}(-1.51V)$.

Teacher: Very good. Therefore, the strongest reducing agent in the question is Al(s).

老師： 還原劑的定義是什麼？

學生： 還原劑是使別人還原，自己發生氧化。

老師： 因此題目中有哪些物質是當還原劑。

學生： $Al, I^{-}\ and\ Mn^{2+}$。

老師： 沒錯，那我們要如何判斷還原劑的強弱呢？

學生： 氧化電位愈大還原劑愈強。

老師： 那這些物質的氧化電位分別為何？

學生： $Al(1.66V) > I^{-}(-0.54V) > Mn^{2+}(-1.51V)$。

老師： 很好。因此題目中最強的還原劑為 Al(s)。

1-5 電解與電鍍
Electrolysis and Electroplating

■ 前言 Introduction

在本小節教師帶學生學習電解裝置與不同環境下產物的差別，並能理解法拉第定律的內容，了解電解的應用並應用電解原理解釋鏽蝕與電鍍，在授課中教師須提醒學生，要區別電池與電鍍的裝置，以及陰陽極和正負極的定義。語言方面，學生能使用相關英文句型描述點電解時不同的化學反應。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electrolysis	電解	electroplating	電鍍
electrolyzer	電解槽	direct current	直流電
power supply	電源供應器	fusion state	熔融態
graphite	石墨	inert electrode	惰性電極
Faraday's laws of electrolysis	法拉第電解定律	proportionality	正比
chlor-alkali industry	鹼氯工業	Downs process	當氏法
electrorefining	電解精煉	corrosion	鏽蝕
electroless plating	無電電鍍		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ is proportional to _____.

例句：In the process of electrolysis, the mass (m) of the same substance deposited **is** directly **proportional to** the amount of electric charge (Q) passed through.

在電解過程中，同一物質析出的質量(m)與通入的電量(Q)成正比。

❷ _____ is/are _____ for the purpose of _____.

例句：Electroplating **is** used to coat the surface of a metal with an inert metal **for the purpose of** rust prevention.

利用電鍍將金屬表面鍍上惰性金屬以達到防鏽的目的。

❸ _____ (be) plated with_____.

例句：Tinplate **is** iron **plated with** zinc.

馬口鐵為鐵鍍上鋅。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出電解的定義。

Students can provide the definition of electrolysis.

二、學生能畫出電解的裝置。

Students can draw the setup of an electrolytic cell.

三、學生能判斷電解裝置的陰、陽極與正、負極。

Students can determine the cathode, anode, positive, and negative electrodes in an electrolytic cell.

四、學生能寫出陰、陽極的反應式與全反應式。

Students can write the reactions and overall reactions at the anode and cathode.

五、學生能寫出在酸、中、鹼性溶液中以惰性電極電解水的反應式。

Students can write the reaction for electrolyzing water using inert electrodes in acidic, neutral, and alkaline solutions.

六、學生能說出法拉第定律的內容。

Students can explain the content of Faraday's laws of electrolysis.

七、學生能了解電解的應用。

Students can understand the applications of electrolysis.

八、學生能應用電解原理解釋鏽蝕與電鍍。

Students can apply the principles of electrolysis to explain corrosion and electroplating.

∞ 例題講解 ∞

例題一

說明：學生能寫出以惰性電極電解水時陰、陽極的反應式，並判斷酸鹼的變化。

Students can write the reactions at the anode and cathode when electrolyzing water using inert electrodes, and can determine changes in acidity and alkalinity.

Before conducting the "Simple Electrolysis" experiment, Teacher Lee demonstrated a basic electrolysis experiment on the laboratory desk for the first-year high school students. Using the setup shown in Figure 12, Teacher Lee used a platinum wire bent into the shape of a needle to serve as an electrode for electrolyzing purple cabbage juice. Soon, the solution on the right side of the partition gradually changed from purple to red, while the solution on the left side of the partition changed from purple to blue and then to green. The students were quite amazed by this experiment, which resembled the "Yinyang Sea." They asked the teacher why. Smiling, Teacher Lee replied, "Think about this. How is it different from electrolyzing water?" and then wrote down Table 1 on the blackboard, explaining the relationship between the color of purple cabbage juice and its pH value.

In the experiment demonstrated by Teacher Lee, which electrode on the left side of the partition would cause the purple cabbage juice to turn green after electrolysis? (Choose two)

(A) anode **(B) cathode**

(C) positive electrodes **(D) negative electrodes**

高一學生要做「簡易電解」實驗之前，李老師先在實驗室的講桌上演示了一個簡易的電解實驗。李老師用圖 12 的裝置，以鉑絲彎成迴紋針的形狀，作為電極以電解紫甘藍汁。不久，即見隔板右邊的溶液由紫色逐漸變為紅色，而隔板左邊的溶液，則由紫色逐漸變為藍色，繼而變為綠色。學生看了這個似同「陰陽海」的實驗相當驚訝，問老師為什麼？李老師笑著說：「想想看，與水的電解有何不同？」，並在黑板上寫了表 1，說明紫甘藍汁顏色與pH值的關係。

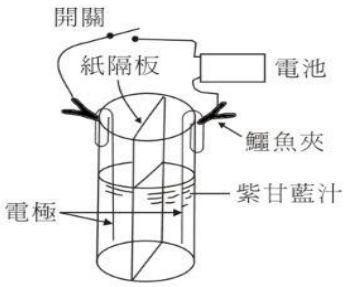

圖 12

表 1

pH值	顏色
2	紅
7	紫
8	藍
10	綠

試問李老師所演示的實驗，其隔板左邊的電極，電解後會使紫甘藍汁變為綠色的是什麼極？（應選兩項）

(A) 陽 極

(B) 陰 極

(C) 正 極

(D) 負 極

（93 年學測 46）

Teacher: The electrode on the left side of the partition in the picture causes the purple cabbage juice to turn into green, indicating a change in the solution after electrolysis. What does this change represent?

Student: According to the table, green corresponds to $pH = 10$, which means the solution becomes alkaline.

Teacher: Correct! Now, please write the reactions at the anode and cathode when water is electrolyzed by using inert electrodes.

Student: Anode: $H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$

Cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$.

Teacher: Very good. So, from the reactions at the anode and cathode, which electrode causes the solution to become alkaline?

Student: The cathode, because hydroxide ions are produced.

Teacher: What reaction occurs at the cathode? Does it gain or lose electrons?

Student: Because of the reduction reaction, it gains electrons.

Teacher: Exactly, so if it gains electrons, which end of the battery should it be connected to?

Student: Negative electrode, because the negative electrode of the battery is where electrons flow out.

Teacher: Excellent! Therefore, the answer to this question is (B)(D).

老師： 請問圖片中隔板左邊的電極會使紫色甘藍汁變成綠色，代表電解後的溶液產生什麼變化？

學生： 從表中得知綠色為$pH = 10$ ，溶液變成鹼性。

老師： 對！那請同學們寫出以惰性電極電解水時陽極與陰極的反應式。

學生： 陽極：$H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$。

陰極：$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$。

老師： 很好，所以從陽極與陰極的反應式我們可以知道是哪一極會使溶液變成鹼性？

學生： 陰極，因為產生了氫氧根離子。

老師： 那陰極是發生什麼反應？得電子還是失電子？

學生： 還原反應，得電子。

老師： 對的，所以如果是得電子應該是連接電池的哪一端？

學生： 負極，因為電池的負極是電子流出端。

老師： 太棒了！所以這題的答案為(B)(D)。

例題二

說明：學生能判斷金屬活性大小與惰性電極的運用。

Students can determine the relative reactivity of metals and understand the application of inert electrodes.

After returning home, student Wang imitated Teacher Lee's experiment and used an iron needle as an electrode to electrolyze purple cabbage juice. However, the result differed from what Teacher Lee had obtained. The next day, Wang described his experimental process and sought guidance from the teacher. After understanding Wang's issue, Teacher Lee took off a gold ring from his finger and said, "Straighten out this ring and use it as an electrode, then try again." Which electrode should Wang use this gold ring as to achieve results similar to Teacher Lee's Yinyang Sea? After electrolysis, what color will be observed on the side where the gold ring is used as the electrode? (Choose two)

(A) Anode

(B) Cathode

(C) First blue, then green

(D) Blue

(E) Red

王同學回家後，模仿李老師也做了同樣的實驗，用鐵質迴紋針當作電極，電解紫甘藍汁，結果與李老師所得的不同。隔天王同學請教了老師，敘述他的實驗經過。李老師瞭解了王同學的問題後，從自己手指上取下了一個金戒指，並說「把這一個戒指拉直後當作電極，再試試看」。試問王同學應將這一個金戒指當作哪一極，才會得到類似李老師的陰陽海？電解後用金戒指作為電極的那一邊，會呈現什麼顏色？（應選兩項）

(A) 陽 極

(B) 陰 極

(C) 先藍後綠

(D) 藍 色

(E) 紅 色

（93 年學測 47）

Teacher: Why did Wang's experiment yield different results from mine?

Student: Because Wang used an iron electrode instead of an inert electrode, causing oxidation to occur during electrolysis.

Teacher: Correct, so which electrode should the gold ring be placed at?

Student: The gold ring is an inert electrode and should be used as the anode. The iron needle should be the cathode to prevent oxidation reactions.

Teacher: Well said. What color would the solution be after electrolysis?

Student: Anode: $H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$ producing H^+ ions and making the solution acidic, corresponding to $pH = 2$ as shown in the table, so the solution would be red.

Teacher: That's correct! Therefore, the answer to this question is (A)(E).

老師： 請問為什麼王同學做的實驗與老師的結果不同？

學生： 因為他拿的電極為鐵，不是惰性電極，在電解的過程中發生氧化了。

老師： 沒錯，所以金戒指應該放在哪一極？

學生： 金戒指為惰性電極，應該當成陽極；鐵質迴紋針應該當陰極，才不會發生氧化反應。

老師： 沒錯，那麼電解後應該會呈現什麼顏色呢？

學生： 陽極：$H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$，產生$H^+$溶液變成酸性，對應到表中$pH = 2$，溶液為紅色。

老師： 答對了！所以這題答案為(A)(E)。

★ 主題二 科學在生活中的運用 ★
Application of Science in Daily Life

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■ 前言 Introduction

在現今便利的社會，化學物質充斥在生活當中，舉凡平常穿在身上的衣著、使用的塑膠製品、喝的水等皆是化學，本章將生活中的科學分成常見的非金屬、金屬、合金及人造聚合物和先進材料介紹，使學生了解這些物質的製備與相關反應。

語言方面，本章節大致圍繞化學元素的形成和特性做介紹，教師可以先教授學生相應的專有名詞，後引導學生透過句型定義、描述金屬的化學作用，也能讓學生試著用英文講述造成某化學氣體或元素鍵結的原因，藉此加強對元素製造的因果關係和混成軌域的多種結構之印象。

2-1 常見非金屬
Common Non-Metals

■ 前言 Introduction

在本小節教師帶學生了解非金屬中氫、碳、氮、氧、矽與其化合物的性質、結構、製備、反應及其應用，並接續高二選修化學II的化學鍵結，教師須注意學生是否理解各結構之間的混成軌域與形狀。

語言方面，老師可以透過不同化學金屬之間的反應，讓學生以主動或被動地句型介紹元素的生成。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
hydrogen	氫	isotopes	同位素
protium	氕	deuterium	氘
tritium	氚	activity	活性
combustibility	可燃性	active metal	活潑金屬
amphoteric metal	兩性金屬	coke	煤焦
cracking reaction	烷類裂解	Haber process	哈柏法
oxyhydrogen flame	氫氧焰	carbon	碳
allotrope	同素異形體	diamond	鑽石 (金剛石)
graphite	石墨	buckyballs	C_{60} (巴克球)

單字	中譯	單字	中譯
carbon fiber	碳纖維	carbon nanotube	奈米碳管
graphene	石墨烯	carbon dioxide	二氧化碳
carbon monoxide	一氧化碳	nitrogen	氮
nitrogen fixation	固氮作用	ammonia	氨
nitric acid	硝酸	Ostwald process	奧士華法
oxygen	氧	ozone	臭氧
silicon	矽		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ exist in the form of _____.

例句：Hydrogen in nature **exists in the form of** diatomic molecule.
自然界的氫皆以雙原子分子的形式存在。

❷ _____ be produced by _____.

例句：Hydrogen gas can **be produced by** reacting active metals with water.
活潑金屬加水可製備出氫氣。

❸ _____ is called _____.

例句：The mixture of carbon monoxide and hydrogen gas **is called** water gas.
一氧化碳與氫氣的混合物稱為水煤氣。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出氫、氮、氧、矽的製備方法。

Students can state the preparation methods for hydrogen, nitrogen, oxygen, and silicon.

二、學生能比較碳的同素異形體其結構與混成軌域。

Students can compare the structures and orbital hybridisation of allotrope of carbon.

三、學生能說出常見的碳、氮、矽的化合物其製備與反應。

Students can state the preparation and reactions of common compounds of carbon, nitrogen, and silicon.

四、學生能比較氧的同素異形體。

Students can compare the allotrope of oxygen.

❧ 例題講解 ☙

例題一

說明：學生能了解活性大於氫的金屬與稀鹽酸、稀硫酸和有機酸反應產生氫氣。

Students can understand that metals with higher reactivity than hydrogen react with dilute hydrochloric acid, dilute sulfuric acid, and organic acids to produce hydrogen gas.

In the following metals, which one will not react with hot dilute sulfuric acid to produce hydrogen gas?

(A) Mg　(B) Al　(C) Fe　**(D) Cu**　(E) Zn

下列金屬中，何者不會與熱稀硫酸溶液反應產生氫氣？

(A) Mg　(B) Al　(C) Fe　**(D) Cu**　(E) Zn

（93 年指考 7）

Teacher: What are the methods of preparing hydrogen in the laboratory?

Student: Hydrogen can be prepared by reacting active metals with acids, amphoteric metals with strong bases, active metals with water, and metal hydrides with water.

Teacher: Great, so based on the description in the question, how can we determine that it belongs to which method?
Student: Reacting active metals with acids.
Teacher: Which metals reacting with acids can produce hydrogen gas?
Student: Metals with reactivity greater than hydrogen.
Teacher: Correct, so the answer is (D).

老師： 請問在實驗室製備氫的方法有哪些？
學生： 可用活潑金屬加酸、兩性金屬加強鹼、活潑金屬加水、金屬氫化物加水。
老師： 很好，那從題目中的敘述我們可以知道是屬於哪一類方法？
學生： 活潑金屬加酸。
老師： 那有那些金屬加酸可以產生氫氣？
學生： 活性大於氫的金屬。
老師： 沒錯，故答案選(D)。

例題二

說明：Students can compare the structure and orbital hybridisation of carbon's isomers and understand the applications of carbon materials.
學生能比較碳的同素異形體其結構與混成軌域及了解碳材料的應用。

In 2010, the Nobel Prize was awarded to scientists who discovered and pioneered research on graphene, which is a single layer of graphite. Which of the following statements about graphene are correct?

(A) The carbon in graphene has sp^2 orbital hybridisation.
(B) Graphene has similar mechanical strength to graphite.
(C) Graphene and graphite have similar opaque black color.
(D) The carbon-carbon bonding in graphene is between a single bond and a double bond.
(E) Graphene consists of only a single atomic layer, so it is a non-conductive molecule.

在 2010 年，諾貝爾獎頒給發現及開創研究石墨烯的科學家，石墨烯是個單層的石墨。下列有關石墨烯的敘述，哪些正確？

(A) 石墨烯中的碳具有 sp^2 混成軌域。

(B) 石墨烯與石墨具有相似的機械強度。

(C) 石墨烯與石墨具有相似的不透明黑色。

(D) 石墨烯中的碳－碳鍵序（鍵數）介於單鍵與雙鍵之間。

(E) 石墨烯只具有單原子層，所以是不導電的分子。

（100 年指考 22）

Teacher: Graphene is a single layer of graphite. What kind of hybrid orbitals are present in carbon in graphene?

Student: Each carbon attached to three other carbons, with three σ bonds and one π bond, creating sp^2 hybrid orbitals.

Teacher: Correct, option (A) is correct. What is the carbon-carbon bonding in graphene?

Student: There are three single bonds and one double bond among the three carbon atoms, and the bonds exhibit resonance. Therefore, the bond order is $1\frac{1}{3}$.

Teacher: Very good, so option (D) is also correct. How can we compare the mechanical strength of the two?

Student: Graphite has weaker van der Waals force between layers, making it easier to slide and giving it a softer texture. Graphene, being a single layer of graphite, is a covalent network solid connected by covalent bonds, giving it a strong texture.

Teacher: So, option (B) is incorrect. What about the color difference between the two?

Student: Graphite is black, while graphene is almost transparent.

Teacher: Therefore, option (C) is also incorrect. What about the conductivity of graphene?

Student: Graphene has delocalized electrons π, making it a conductive covalent network solid.

Teacher: Very good, so option (E) is also incorrect. The correct answers to this question are (A) and (D).

老師：石墨烯是單層的石墨，請問石墨烯中的碳是哪一種混成軌域？

學生：每個 C 與 3 個 C 鍵結，3 個σ鍵，1 個π鍵，為sp^2混成軌域。

老師：沒錯，(A)選項為正確的。那碳碳鍵數為何？

學生：3 個碳之間共有 3 個σ鍵，1 個π鍵，且π 鍵會共振，因此鍵級為 $1\frac{1}{3}$。

老師：很好，所以(D)選項也是對的。那我們要如何比較兩者間的機械強度呢？

學生：石墨層和層間有較弱的凡得瓦力，容易滑動所以質地較軟，石墨烯為單層的石墨，是共價網狀固體，由共價鍵連接故質地堅固。

老師：所以(B)選項是錯誤的。那顏色兩者之間有什麼不同？

學生：石墨為黑色的，石墨烯幾乎透明。

老師：因此(C)選項也是錯誤的。那石墨烯的導電性為何？

學生：石墨烯具有未定域的π電子，因此是可導電的共價網狀固體。

老師：很好，所以(E)選項也是錯誤的，這一題的正確答案為(A)(D)。

2-2 常見金屬
Common Metals

■ 前言 Introduction

在元素週期表中大約有 $\frac{4}{5}$ 的元素為金屬，其中具有許多不同的化學性質、硬度、密度等，在我們的生活中應用也十分廣泛，例如鐵製品、鋁製品，高一化學全中僅敘述常見到的鹼金屬與鹼土金屬，而本章節接續概念並延伸學習常見的主族與過渡金屬其製備、性質與用途。配位化合物對於學生為較新的概念，特別是配位基與配位數的計算教師須特別留意。

語言方面，老師可以透過生活中常見的化學元素讓學生運用相應單字介紹，並用句型描述不同元素的準備方式，特性和應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
alkali metal	鹼金屬	sodium	鈉
flame	焰色	sodium chloride	氯化鈉
sodium hydroxide	氫氧化鈉	sodium carbonate	碳酸鈉
sodium bicarbonate	碳酸氫鈉	Solvay process	索耳末法
alkaline earth metal	鹼土金屬	magnesium	鎂
magnesium oxide	氧化鎂	magnesium sulfate	硫酸鎂
aluminum	鋁	bauxite	鋁礬土

單字	中譯	單字	中譯
Hall process	霍爾法	alumina oxide	氧化鋁
aluminum hydroxide	氫氧化鋁	alum	明礬
transition metal	過鍍金屬	iron	鐵
coordination complex	配位化合物 (錯合物)	ligand	配位基
coordination number	配位數	hemoglobin	血紅素
chlorophyll	葉綠素		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ exhibit(s) _____.

例句：Sodium salts **exhibit** a yellow flame color when burned.

鈉鹽於火焰中呈現黃色焰色。

❷ _____ is commonly known as _____.

例句：Sodium carbonate **is commonly known as** baking soda.

碳酸鈉俗稱蘇打。

❸ _____ is related to _____.

例句：The number of ligands **is related to** the size, charge, and electron configuration of the central metal.

配位數的多寡與中心金屬的大小、電荷數與電子組態有關。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能講出常見主族金屬的性質與檢驗。

Students should be able to describe the properties and examination of common main-group metals.

二、學生能寫出常見主族金屬的製備的方法與其反應式。

Students should be able to write the methods for preparing common main-group metals and their reaction equations.

三、學生能寫出金屬的化合物的相關反應。

Students should be able to write reactions involving metal compounds.

四、學生能講出常見主族化合物的俗名。

Students should be able to name common main-group compounds.

五、學生能比較鈉、鎂、鋁三種元素的性質。

Students should be able to compare the properties of sodium, magnesium, and aluminum.

六、學生能講出常見過渡金屬的性質及製備方法。

Students should be able to describe the properties and preparation methods of common transition metals.

七、學生能分辨金屬離子的顏色。

Students should be able to distinguish the colors of metal ions.

八、學生能講出配位化合物的鍵結原理。

Students should be able to explain the bonding principles in coordination compounds.

九、學生能分類配位子。

Students should be able to classify ligands.

十、學生能計算配位化合物的配位數。

Students should be able to calculate the coordination number of coordination compounds.

∞ 例題講解 ∞

例題一

說明：學生能寫出金屬化合物的相關反應。

Students can write the relevant reactions of metal compounds.

In the process of bread making, baking soda ($NaHCO_3$) is commonly used as a leavening agent. However, before the use of baking soda, ammonium bicarbonate (NH_4HCO_3) was also used as a leavening agent for such food products. When using ammonium bicarbonate, during the bread baking process (approximately 190 to 230 °C), three gasses, A, B, and C, are released. Among them, A has a pungent odor, while B and C are odorless. If baking soda is used to bake bread at the same temperature range, two gasses and sodium carbonate (Na_2CO_3) will be produced. Which of the following statements regarding these two baking processes are correct?

(A) 1 mole of ammonium bicarbonate produces 4 moles of gas.

(B) 1 mole of baking soda produces 3 moles of gas.

(C) A is not produced when using baking soda.

(D) B and C are produced when using baking soda.

(E) A produced when using ammonium bicarbonate is urea ($(NH_2)_2CO$).

在麵包的製作過程中，常以小蘇打（$NaHCO_3$）做為膨鬆劑，然而在使用小蘇打之前，碳酸氫銨（NH_4HCO_3）亦曾是這類食品的膨鬆劑。使用碳酸氫銨時，於麵包烘焙過程中（約 190 至 230 ℃）會釋出甲、乙與丙三種氣體，其中甲有刺鼻味，而乙與丙均沒有味道。若於同溫度範圍內使用小蘇打烘焙麵包時，則會產生兩種氣體及碳酸鈉（Na_2CO_3）。下列有關此兩種烘焙過程的敘述，哪些正確？

(A) 每 1 莫耳的碳酸氫銨會產生 4 莫耳的氣體。

(B) 每 1 莫耳的小蘇打會產生 3 莫耳的氣體。

(C) 使用小蘇打時，不會產生甲。

(D) 使用小蘇打時，會產生乙與丙。

(E) 使用碳酸氫銨時，所產生的甲是尿素($(NH_2)_2CO$)。

（107 年指考 24）

Teacher: Please write the reaction equation for the heating of ammonium bicarbonate (NH_4HCO_3).

Student: $NH_4HCO_3(s) \xrightarrow{\triangle} NH_3(g)+H_2O(g)+CO_2(g)$.

Teacher: That's correct. So, we can tell that for every mole of ammonium bicarbonate, three moles of gas are produced. Now, can you tell me what the pungent gas of A is?

Student: Water vapor and carbon dioxide are odorless, so the pungent gas is ammonia gas.

Teacher: Very good. Therefore, options (A) and (E) are incorrect. Now, please write the reaction equation for sodium bicarbonate ($NaHCO_3$) when it is heated.

Student: $NaHCO_3 \xrightarrow{\triangle} Na_2CO_3(s)+H_2O(g)+CO_2(g)$.

Teacher: Excellent! So, every mole of sodium bicarbonate will produce two moles of gas, which are water vapor and carbon dioxide. Therefore, the correct answers for this question are options (C) and (D).

老師： 請同學寫出 碳酸氫銨（NH_4HCO_3）加熱時的反應式。

學生： $NH_4HCO_3(s) \xrightarrow{\triangle} NH_3(g)+H_2O(g)+CO_2(g)$ 。

老師： 沒錯，因此我們可以知道每一莫耳的碳酸氫銨產生了三莫耳的氣體。那請問具刺鼻性氣體甲為何？

學生： 水蒸氣與二氧化碳均無味道，因此甲氣體為氨氣。

老師： 很好，因此(A)(E)選項為錯誤的。那同學請寫出小蘇打（$NaHCO_3$）受熱反應式。

學生： $NaHCO_3 \xrightarrow{\triangle} Na_2CO_3(s)+H_2O(g)+CO_2(g)$。

老師： 很棒！因此每一莫耳的碳酸氫鈉會產生 2 莫耳的氣體，且氣體為水蒸氣和二氧化碳。所以這一提的正確解答為(C)(D)。

例題二

說明：學生能計算配位化合物的配位數。

Students can calculate the coordination number of coordination compounds.

The dissolved oxygen level in cell culture media is hard to detect, but it can be measured using certain specific complex compounds. In solution, the fluorescence signal intensity of the complex compound decreases with increasing oxygen concentration. One ruthenium complex compound, with the chemical formula $[RuL_3]Cl_2$, exhibits this property. Ru is coordinated with three ligands L. Figure 7 shows the structural formula of ligand L. Which of the following statements about this complex compound is correct?

(A) Ru is a +2 valence ion.

(B) Ligand L is a monodentate ligand.

(C) $[RuL_3]Cl_2$ is a 6-coordinate complex.

(D) The coordination complex has 21 double bonds.

(E) Precipitation occurs when silver nitrate solution reacts with a complex solution.

細胞培養液中的溶氧量不易偵測，但利用某些特定錯合物的螢光則可以測得。於溶液中，錯合物的螢光訊號強度，會隨氧氣的濃度增加而下降。某一個釕錯合物，即有此種性質，其化學式為$[RuL_3]Cl_2$ 其中，Ru 與三個配位基 L 錯合。圖 7 為配位基 L 的結構式。下列有關此錯合物的敘述，哪些正確？

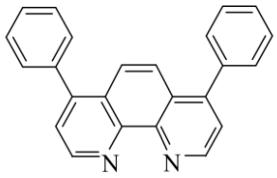


圖 7

(A) Ru 為+2 價離子。

(B) 配位基 L 是單牙基。

(C) $[RuL_3]Cl_2$ 為 6 配位的錯合物。

(D) 錯合物具有 21 個雙鍵。

(E) 硝酸銀溶液和錯合物溶液作用可產生沉澱。

（110 年指考 21）

Teacher: How can we determine the valence number of Ru in the ruthenium complex?

Student: $[RuL_3]Cl_2 \rightarrow [RuL_3]^{2+} + 2\ Cl^-$, and from the structure in Figure 7, we can see that L is a neutral molecule, so Ru^{2+} is a +2 valence cation.

Teacher: That's correct, so option (A) is correct. How can we determine if ligand L is monodentate or polydentate?

Student: Each of the two nitrogen atoms on the ligand has one lone pair of electrons, so it is a bidentate ligand.

Teacher: Great! So, option (B) is incorrect. How can we determine the coordination number of Ru^{2+}?

Student: We can determine it from the number of bonds between the central metal and the ligands. Ru^{2+} forms bonds with 3 bidentate ligands, so $[RuL_3]Cl_2$ is a 6-coordinate complex.

Teacher: That's right! So, option (C) is correct. And can you tell how many double bonds the complex has?

Student: Each ligand has 13 double bonds, and there are a total of six ligands, so there are 39 double bonds.

Teacher: So, option (D) is incorrect. How can we determine if a precipitate is formed when silver nitrate is added to the complex solution?

Student: The complex dissociates and produces Cl^-, which reacts with Ag from silver nitrate to form a precipitate: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$.

Teacher: That's correct! So, the correct answers for this question are (A), (C), and (E).

老師： 我們可以如何知道釕錯合物中 Ru 的價數？

學生： $[RuL_3]Cl_2 \rightarrow [RuL_3]^{2+} + 2\ Cl^-$，且從圖七的結構可以知道 L 為分子，不帶電，因此 Ru^{2+}為+2 價的陽離子。

老師： 沒錯因此(A)選項是正確的。那我們如何知道配位子 L 為單牙基或是多牙基？

學生： 配位子上的 2 個 N 原子上有各有一個孤對電子，因此為雙牙配位子。

老師： 很好！所以(B)選項是錯誤的。那我們如何知道 Ru^{2+}的配位數。

學生： 可從中心金屬與配位子間的鍵結數目得知，Ru^{2+}與 3 個雙牙基配位子鍵結，因此$[RuL_3]Cl_2$ 為 6 配位錯合物。

老師： 太好了！所以(C)選項是正確的。並請各位判斷該錯合物有幾個雙鍵。

學生： 每個配位子有 13 個雙鍵，共六個配位子，故有 39 個雙鍵。

老師： 所以(D)選項是錯誤的，那我們如何判斷硝酸銀與錯合物溶液是否產生沉澱？

學生： 錯合物解離會產生 Cl^-，與硝酸銀解離出的Ag^+產生沉澱：$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$。

老師： 沒錯！所以這題的正確答案為(A)(C)(E)。

2-3 常見合金
Common Alloy

■ 前言 Introduction

本小節介紹常見的合金，學生能了解合金上的應用已有很久遠的歷史，從歷史課本中的青銅器，到現今常見的不銹鋼，皆是合金，其性質透過不同金屬的混合有較多的變化性，因此其應用範圍較純金屬更為廣泛。教師在授課時須注意學生是否了解各項合金的組成。語言方面，老師可以用分類法引導學生了解合金的種類，以英文的字根字首做詳細的介紹也能當作分辨合金的初步判斷，而後用「包含」、「組成」的句型讓學生進行小組練習以釐清觀念。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
alloy	合金	bronze	青銅器
copper	銅	tin	錫
gold	黃金	white gold	白金 (K 金)
platinum	白金	silver	銀
nickel	鎳	pig iron	生鐵
wrought ingot	熟鐵	steel	鋼
tungsten steel	鎢鋼	wolfram	鎢
chromium	鉻	manganese	錳

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ is one-third of ___(N)___.

例句：The mass of aluminum **is** approximately **one-third of** that of iron.

鋁的質量約為鐵的 1/3。

❷ _____ an alloy consisting of _____.

例句：Bronze is **an alloy consisting of** copper and tin.

青銅器是含有銅與錫的合金。

❸ _____ are suitable for _____.

例句：Metals **are suitable for** making various instruments and tools.

金屬適合用來製作各種器械與工具。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出合金的定義、鍵結、性質與熔點特性。

Students can explain the definition, bonding, properties, and melting point characteristics of alloys.

二、學生能說出金、鋁、鐵合金的主要成分。

Students can state the main components of gold, aluminum, and iron alloys.

例題講解

例題一

說明：學生能了解金屬合金的特性。

Students can understand the characteristics of metal alloys.

A commercially available metal blackening agent is composed of potassium chlorate（$KClO_3$）and another substance X. If a zinc plate is placed in the blackening agent, the surface of the zinc plate can be dyed red first and then turn black. Which of the following options could be the other substance X in the blackening agent?

(A) Iron powder　(B) Graphite powder　(C) Black paint

(D) Zinc carbonate　**(E)Copper sulfate**

市售一種金屬染黑劑，是由氯酸鉀（$KClO_3$）與另一物質 X 所組成。若將鋅板置於該染劑中，可將鋅板表面先染成紅色，繼而變成黑色。試問下列哪一選項可能是該染劑所含的另一物質 X ？

(A) 鐵粉　(B) 石墨粉　(C) 黑色油漆

(D) 碳酸鋅　**(E) 硫酸銅**

（103 年指考 7）

Teacher: The surface of zinc turns red. What substance is most likely to be?

Student: Copper, because its color is red.

Teacher: That's correct! So, what is the role of copper ions?

Student: Copper ions act as oxidizing agents, while zinc acts as a reducing agent, reducing copper ions to form copper metal.

Teacher: Exactly! Now, what is the role of potassium chlorate?

Student: Potassium chlorate acts as an oxidizing agent, causing the copper metal to oxidize into black copper oxide.

Teacher: Very good! So, the answer will be option (E).

老師： 鋅表面染成紅色，請問最有可能是何種物質？
學生： 銅，因為其顏色為紅色。
老師： 沒錯！那請問銅離子的作用為何？
學生： 銅離子當成氧化劑，鋅當還原劑，還原出銅金屬。
老師： 對的！那請問氯酸鉀的作用為何？
學生： 氯酸鉀當氧化劑使銅金屬氧化成黑色的氧化銅。
老師： 很好！所以這題的答案為(E)選項。

例題二

說明：學生能了解合金與其成分的反應。

Students can understand the reactions of alloys and their components.

Wang wants to analyze the composition proportion of an aluminum-magnesium alloy. It is known that both aluminum and magnesium can react with hydrochloric acid to produce hydrogen gas (unbalanced reaction equations like Equation 1 and Equation 2). If equal weights of the aluminum-magnesium alloy and pure aluminum are separately reacted with an excess of hydrochloric acid, and then the volumes of hydrogen gas collected under the same conditions are measured, the composition proportion can be determined. If the measured proportion of hydrogen gas volume (aluminum-magnesium alloy: pure aluminum) is 9:10, what is the weight percentage of aluminum in the alloy (which contains only aluminum and magnesium)? (Mg=24 , Al=27)

(A) 20　(B) 40　**(C) 60**　(D) 70　(E) 80

王同學想分析某鋁鎂合金的成分比例，已知鋁和鎂都可以和鹽酸反應產生氫氣（未平衡的反應式如式 1 和式 2）。如果用等重量的鋁鎂合金和純鋁片，分別和過量的鹽酸反應，再測量在相同條件下所收集到的氫氣體積比，應可決定出其成分比例。若所測得的氫氣體積比（鋁鎂合金：純鋁）為 9：10，則該合金（只含鋁和鎂）中，鋁所占的重量百分比為何？(Mg=24 , Al=27)

$Al(s)+HCl(aq)\rightarrow AlCl_3(aq)+H_2(g)$　式 1

$Mg(s)+HCl(aq)\rightarrow MgCl_2(aq)+H_2(g)$　式 2

(A) 20　(B) 40　**(C) 60**　(D) 70　(E) 80

（110 年學測試辦 12）

Teacher: Please balance reaction equations 1 and 2.

Student: $Al(s)+3HCl(aq)\rightarrow AlCl_3(aq)+\frac{3}{2}H_2(g)$

$Mg(s)+2HCl(aq)\rightarrow MgCl_2(aq)+H_2(g)$

Teacher: How do we determine the molar ratio of hydrogen gas?

Student: According to Avogadro's law, the volume ratio of gasses is equal to the molar ratio under the same temperature and pressure. Therefore, the molar ratio of hydrogen gas (aluminum-magnesium alloy: pure aluminum) is 9:10.

Teacher: That's correct! If we assume that 27 g of pure aluminum produces 1.5 moles of hydrogen gas, then how many moles of hydrogen gas are produced by the aluminum-magnesium alloy?

Student: $9:10=x:1.5$

$x=\frac{9\times1.5}{10}=1.35(\text{mol})$

Teacher: That's right. Therefore, the aluminum-magnesium alloy, which weighs the same (27 g), produces 1.35 moles of hydrogen gas. If we assume the moles of aluminum and magnesium are represented by m and n, what is the relationship between them?

Student: $27m+24n=27$

$1.5m+n=1.35$

$m=0.6\ ,\ n=0.45$

$\text{aluminum}=\frac{27\times0.6}{27}\times100\%=60\%$

Teacher: Very good! So, the answer will be option (C).

老師： 請平衡式 1 及式 2 的反應。

學生： $Al(s)+3HCl(aq)\rightarrow AlCl_3(aq)+\frac{3}{2}H_2(g)$

$Mg(s)+2HCl(aq)\rightarrow MgCl_2(aq)+H_2(g)$

老師： 那我們如何得知氫氣的莫耳數比？

學生： 根據亞佛加厥定律，同溫同壓下氣體的體積比等於莫耳數比，因此氫氣的莫耳數比（鋁鎂合金：純鋁）為 9：10。

老師：沒錯！若我們假設取 27 g 的純鋁片反應產生的氫氣為 1.5 mol，那麼鋁鎂合金生的氫氣莫耳數為何？

學生：$9:10 = x:1.5$

$x = \frac{9\times1.5}{10} = 1.35(\text{mol})$

老師：沒錯，因此等重 （27 g）的鋁鎂合金反應產生的氫氣莫耳數為 1.35 mol。若假設鋁及鎂的莫耳數分別為 m 及 n，請問他們之間有什麼關係？

學生：$27m + 24n = 27$

$1.5m + n = 1.35$

$m = 0.6$，$n = 0.45$

鋁=$\frac{27\times0.6}{27} \times 100\% = 60\%$。

老師：對！所以這題的答案為(C)選項。

2-4 人造聚合物 Synthetic Polymers

■ 前言 Introduction

人造聚合物大量運用於生活中，從纖維、塑膠製品到橡膠，增加方便性的同時也須注意他們對於環境上的影響，教師在本小節須特別講解各聚合物的單體及其聚合的方式，也能將環境教育與情意發展帶入課程中。

語言方面，可以帶入句型引導學生了解聚合物的組成方式，並且以開放性問題讓學生認知其對環境的影響力，並用簡單的英文句子回答。

■ 詞彙 Vocabulary

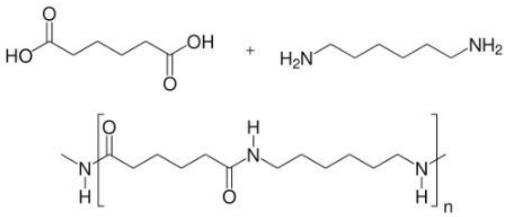
單字	中譯	單字	中譯
polymer	聚合物	molecule	分子
mixture	混合物	synthetic fiber	合成纖維
cellulose	纖維素	glucose	葡萄糖
protein	蛋白質	amino acid	胺基酸
synthetic fiber	合成纖維	polyamide	聚醯胺
polyester	聚酯	blending	混紡
synthetic plastic	合成塑膠	thermoplastic	熱塑性
thermosetting	熱固性	natural rubber	天然橡膠
synthetic rubber	合成橡膠		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ is formed by the polymerization of _____ and _____.

例句：The monomer of Nylon-66 **is formed by the polymerization of** hexanedioic acid **and** hexamethylenediamine.

耐綸-66 的單體為己二酸與己二胺聚合而成。



❷ _____ be composed of _____.

例句：Cellulose **is composed of** glucose units.

纖維素由葡萄糖組合而成。

❸ _____ is primarily used to _____.

例句：Polybutadiene rubber **is primarily used to** make tires.

聚丁二烯橡膠主要用來製作輪胎。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出聚合物的定義與特性。

Students can state the definition and characteristics of polymers.

二、學生能分辨天然纖維與合成纖維。

Students can distinguish between natural fibers and synthetic fibers.

三、學生能分類並比較熱塑性與熱固性塑膠。

Students can classify and compare thermoplastic and thermosetting plastics.

四、學生能對照回收標誌說出其名稱，單體組成、特性和應用。

Students can identify and describe recycling symbols, monomer composition, characteristics, and applications.

五、學生能分辨天然橡膠與合成橡膠。

Students can distinguish between natural rubber and synthetic rubber.

六、學生能說出各聚合物的單體。

Students can name the monomers of each polymer.

七、學生能了解塑膠對生態的危害並落實垃圾分類與減塑行動。

Students can understand the environmental impact of plastics and implement waste separation and plastic reduction initiatives.

例題講解

例題一

說明：學生可分辨聚合物的種類並從單體判別聚合的方式。

Students can distinguish between different types of polymers and determine the polymerization method from the monomers.

Polylactic acid (PLA) is an environmentally friendly and biodegradable polymer that can be polymerized from monomer A or monomer B, as shown in Figure 8. Which of the following statements are correct?

(A) PLA is a polyether polymer.

(B) PLA is not easily soluble in water.

(C) Monomer B can directly undergo a condensation reaction with dehydration to form PLA.

(D) Using equal moles of monomer A and monomer B for polymerization produces equal weights of PLA.

(E) Using equal weights of monomer A and monomer B for polymerization, monomer B can result in the formation of heavier PLA.

聚乳酸是一種環境友善、可降解的聚合物，可由單體甲或單體乙聚合而成，其結構如圖 8。下列相關的敘述，哪些正確？

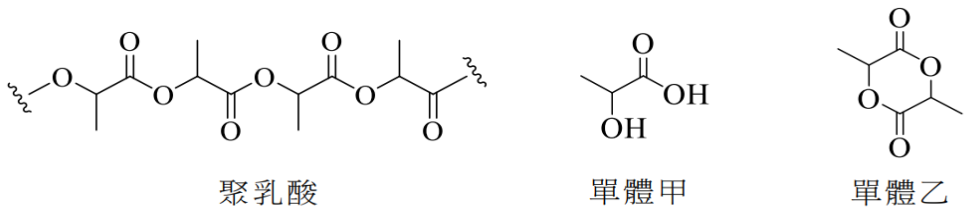


圖 8

(A) 聚乳酸為聚醚類聚合物。

(B) 聚乳酸不易溶於水。

(C) 單體乙可直接經由縮合反應脫水生成聚乳酸。

(D) 使用等莫耳數的單體甲及單體乙分別進行聚合，可生成等重量的聚乳酸。

(E) 使用等重量的單體甲及單體乙分別進行聚合，後者可生成較重的聚乳酸。

（110 年分科 22）

Teacher: From the structural formula of polylactic acid (PLA) in the figure, how can we determine which class of polymers it belongs to?

Student: A polyester! Because it contains COO functional groups.

Teacher: That's correct. Therefore, option (A) is incorrect. How can we determine its solubility in water?

Student: Polymers are high-molecular-weight substances, and their solubility in water is generally low.

Teacher: So, option (B) is correct. How do monomer A and monomer B polymerize?

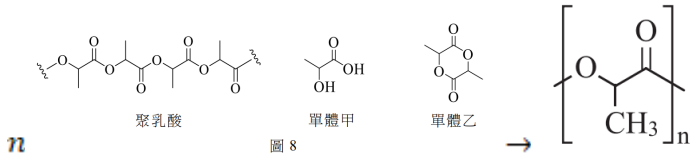
Student: Monomer A undergoes a dehydration polymerization to form polylactic acid, while monomer B undergoes ring-opening polymerization after adding water to form polylactic acid.

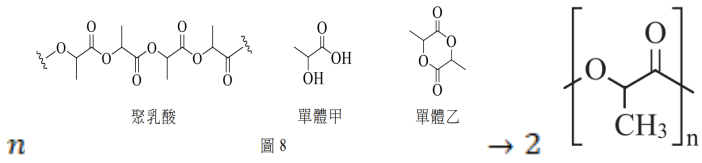
Teacher: Therefore, option (C) is incorrect. Then which one is heavier when equal weights of monomer A and monomer B are polymerized separately?

Student: Monomer A undergoes dehydration during polymerization, resulting in a lighter weight after polymerization, while monomer B results in a heavier weight after polymerization.

Teacher: That's correct! Therefore, option (E) is correct. When equal moles of monomer A and monomer B are separately polymerized, what is the approximate weight ratio of the resulting polymers?

Student:





The weight ratio is approximately 1:2.

Teacher: Very good! So, the answers will be option (B) and (E).

老師：　從圖中聚乳酸的結構式我們可以知道它屬於哪一類聚合物？

學生：　聚酯類，因為其中具有 COO 的官能基。

老師：　沒錯，因此(A)選項錯誤。那我們如何判斷其對水的溶解度？

學生：　聚合物為高分子物質，對水的溶解度低。

老師：　所以(B)選項是正確的。那單體甲和乙分別如何聚合？

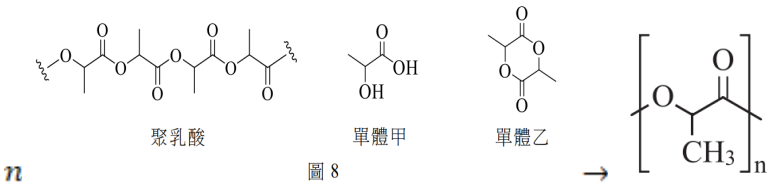
學生：　單體甲經脫水聚合成聚乳酸；單體乙加水後再開環縮合聚合成聚乳酸。

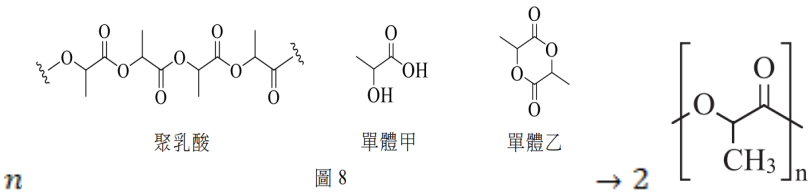
老師：　因此(C)選項錯誤。因此等重單體分別進行聚合何者重量較重。

學生：　單體甲聚合時需脫水因此聚合後重量較輕，單體乙聚合後較重。

老師：　沒錯！因此(E)選項正確。使用等莫耳數的單體甲及單體乙分別進行聚合時，生成的重量比約為多少？

學生：





重量比約為 1：2。

老師：　很好！所以這題的答案為(B)(E)。

例題二

說明：學生能根據聚合物的結構式分辨其單體為何。

Students can identify the monomers of a polymer based on its structural formula.

Synthetic rubber is commonly used as a material for car tires. The local chemical structure of a specific synthetic rubber is shown in Figure 6. This synthetic rubber is a linear polymer formed by repeating the carbon-carbon bond formation through one end carbon atom of monomer compound A, and this process does not produce any other byproducts. What is the approximate molecular weight of monomer compound A?

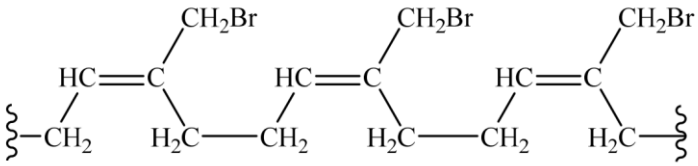


圖 6

(A) 54　(B) 68　(C) 100　**(D) 147**　(E) 161

合成橡膠常做為汽車輪胎的材料。某一合成橡膠的局部化學結構如圖 6 所示。此合成橡膠是以化合物甲為單體，彼此透過一端碳原子進行碳-碳鍵結，如此重複進行而成的鏈狀聚合物，此過程無其他副產物生成。試問單體化合物甲的分子量約為多少？

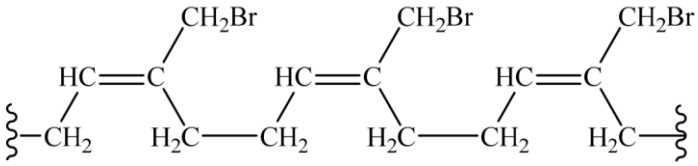


圖 6

(A) 54　(B) 68　(C) 100　**(D) 147**　(E) 161

（109 年指考 14）

Teacher: Based on the structure of the polymer in the diagram, please identify the repeating portion.

Student:

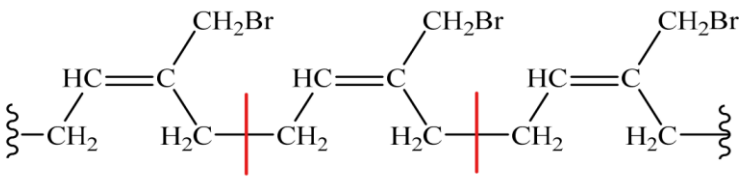


圖 6

Teacher: Therefore, from this repetitive pattern, can we deduce the monomer?

Student: $CH_2=CH-C(CH_2Br)=CH_2$.

Teacher: Very good. What is the molecular weight of this monomer?

Student: The molecular formula is C_2H_2Br, and the molecular weight is $12\times5+1\times7+79.9\times1=146.9$

Teacher: That's correct! So, the correct answer to this question is option (D).

老師： 請根據圖中的聚合物結構切分出重複的部分。

學生：

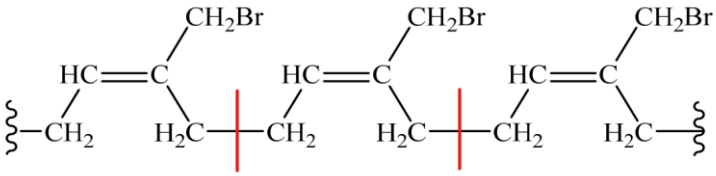


圖 6

老師： 因此從這個重複的趨勢我們可以回推其單體為何？

學生： $CH_2=CH-C(CH_2Br)=CH_2$。

老師： 很好，那這個單體的分子量為何？

學生： 分子式為 C_2H_2Br，分子量為 $12\times5+1\times7+79.9\times1=146.9$。

老師： 沒錯！所以這題的正確答案為(D)選項。

2-5 先進材料
Advanced Materials

■ 前言 Introduction

在本小節教師帶學生了解新興的化學材料，像是半導體、液晶、導電塑膠、奈米材料其成分、特性及應用。

語言方面，學生能認識到與新科技相關的單字，並透過不同化學材料的特性學習「增強，上升」等描述圖表時可以表達的單字。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
semiconductor	半導體	silicon	矽
germanium	鍺	energy band	能帶
band gap	能隙	diode	二極體
transistor	三極體(電晶體)	integrated circuit (IC)	積體電路
liquid crystal	液晶	liquid crystal display (LCD)	液晶顯示器
conductive plastic	導電塑膠	organic light-emitting diode (OLED)	有機發光二極體
nanomaterials	奈米材料	Lotus effect	蓮花效應
superhydrophobic	超疏水	surface-area-to-volume ratio	比表面積
quantum effect	量子效應		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ increase(s) with _____.

例句：Semiconductor conductivity **increases with** rising temperature.

半導體的導電性隨溫度升高而增大。

❷ _____ is divided into _____.

例句：The energy band **is divided into** valence band and conduction band.

能帶分為價帶與傳導帶。

❸ _____ exhibit _____ properties.

例句：Nanomaterials **exhibit** superhydrophobic **properties**.

奈米材料具有超疏水的特性。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this chapter, students should be able to know that:

一、學生能說出半導體的元素與性質。

Students can state the elements and properties of semiconductors.

二、學生能解釋能帶理論。

Students can explain the energy band theory.

三、學生能比較金屬導體、半導體與絕緣體的能隙與導電關係。

Students can compare the energy band gap and conductivity relationships in metal conductors, semiconductors, and insulators.

四、學生能分辨 p 型及 n 型半導體。

Students can distinguish p-type and n-type semiconductors.

五、學生能說出二極體、三極體與積體電路的組成與應用。

Students can describe the composition and applications of diodes, transistors, and integrated circuits (ICs).

六、學生能說出液晶的狀態、材料、特性與應用。

Students can explain the states, materials, characteristics, and applications of liquid crystals.

七、學生能寫出導電塑膠的結構並說明其導電原理和用途。

Students can write the structure of conductive plastics and explain their conductivity principles and uses.

八、學生能定義奈米材料並說其獨特性。

Students can define nanomaterials and describe their unique properties.

例題講解

例題一

說明：學生能了解奈米材料的特性。

Students can understand the properties of nanomaterials.

Silver nanoparticles of different sizes exhibit different optical properties, with some emitting light when illuminated and others not. Silver nanoparticles used for sterilization on the market are larger and do not emit light, while silver nanoparticles composed of dozens of silver atoms can emit light. A simple method for synthesizing luminescent silver nanoparticles is to add DNA and silver ions to a neutral aqueous solution and then add $NaBH_4$ to form silver nanoparticles. In this synthesis, DNA primarily forms complexation with silver ions to prevent the formation of silver hydroxides or oxides. At the same time, DNA can also protect the formed silver nanoparticles, keeping them stable in the aqueous solution and reducing their interaction with oxygen. Based on the above information, which of the following statements are correct?

(A) $NaBH_4$ is a reducing agent.

(B) DNA is an oxidizing agent.

(C) DNA's bases have lone pairs of electrons (lone electron pairs).

(D) Oxygen oxidizes silver nanoparticles.

(E) In an alkaline aqueous solution, silver ions react with hydroxide ions to produce silver atoms.

不同尺寸的銀奈米粒子具有不同的光學特性，有的在光照後會發光，有的不會。市面上用於殺菌的銀奈米粒子，顆粒較大且不會發光，但由數十個銀原子組成的銀奈米粒子則可發光。合成可發光銀奈米粒子的簡單方法是將 DNA 和銀離子加入中性水溶液中，再加入 $NaBH_4$ 使其形成銀奈米粒子。在合成中，DNA 主要是和銀離子形成錯合物，避免形成銀的氫氧化物或氧化物，同時 DNA 亦可保護所形成的銀奈米粒子，使其穩定存於水溶液中並降低其和氧氣作用的程度。根據上文，下列相關敘述，哪些正確？

(A) $NaBH_4$ 為還原劑。

(B) DNA 為氧化劑。

(C) DNA 的鹼基具有孤對電子（孤電子對）。

(D) 氧氣會氧化銀奈米粒子。

(E) 於鹼性水溶液中，銀離子會和氫氧根離子作用產生銀原子。

（109 年指考 14）

Teacher: Please write the reaction for the formation of silver nanoparticles when silver ions are added to $NaBH_4$.

Student: $2Ag^{+}+2NaBH_4 \rightarrow 2Ag+H_2+B_2H_4+2Na^{+}$.

Teacher: That's correct! So in the reaction, what are the oxidizing and reducing agents, respectively?

Student: Silver ions are reduced to nano-silver, so silver ions act as the oxidizing agent; $NaBH_4$ is oxidized to B_2H_4, so $NaBH_4$ is the reducing agent.

Teacher: So, option (A) is correct, and option (B) is incorrect. How do we determine if DNA's nucleobases have lone pairs of electrons?

Student: DNA can form complexes with silver ions, indicating that DNA's bases have lone pairs of electrons and can act as ligands.

Teacher: Very good! So, option (C) is correct. What other reactions can occur with silver nanoparticles?

Student: Silver nanoparticles have a total surface area and high reactivity, making them prone to oxidation reactions with oxygen. Additionally, they can react in an alkaline solution: $2Ag^{+}(aq)+2OH^{-}(aq) \rightarrow 2AgOH(s) \rightarrow Ag_2O(s)+H_2O(l)$.

Teacher: That's correct! So, the correct answers for this question are (A), (C), and (D).

老師： 請寫出銀離子加入 $NaBH_4$ 形成銀奈米粒子的反應式。

學生： $2Ag^+ + 2NaBH_4 \rightarrow 2Ag + H_2 + B_2H_4 + 2Na^+$。

老師： 沒錯！所以在反應式中氧化劑與還原劑分別為何？

學生： 銀離子還原為奈米銀，因此銀離子當氧化劑；$NaBH_4$ 氧化成 B_2H_4，因此 $NaBH_4$ 為還原劑。

老師： 所以(A)選項正確，(B)選項錯誤。我們如何判斷 DNA 的鹼基是否具有孤對電子？

學生： DNA 和銀離子可以形成錯合物，可得知 DNA 的鹼基具有孤對電子，可當配位子。

老師： 很好！所以(C)選項是正確的。那銀奈米粒子還會發生哪些反應？

學生： 銀奈米粒子因總表面積大故活性大，容易與氧發生氧化反應，且於鹼性的溶液中會發生反應：$2Ag^+(aq) + 2OH^-(aq) \rightarrow 2AgOH(s) \rightarrow Ag_2O(s) + H_2O(l)$.

老師： 沒錯！所以這一題的正確答案為(A)(C)(D)。

例題二

說明：學生能了解半導體的鍵結方式。

Students can understand the bonding of semiconductors.

Silicon crystal (Si) is an important material for semiconductors and solar panels. Silicon atoms in the crystal, like diamonds, form sp^3 hybrid orbitals with four neighboring silicon atoms.

If one silicon atom is located at the center position 1 in Figure 4, where are the positions of the other silicon atoms adjacent to this silicon atom? (Note: Center position is 1, the other corner positions are 2-9)

(A) 2,3,4,5

(B) 2,4,7,9

(C) 2,4,5,7

(D) 3,6,7,9

(E) 3,7,8,9

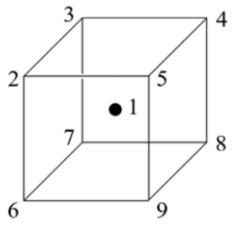


圖 4

矽晶（Si）為半導體及太陽能板的重要材料。晶體中的矽原子如金剛石一樣，與鄰近的四個矽原子以 sp^3 混成軌域鍵結。若一個矽原子位於圖 4 中正立方體之中心位置 1 處，則緊鄰此矽原子的其他矽原子的位置為何？（註：中心位置為 1，其他角落位置為 2–9）

(A) 2,3,4,5

(B) 2,4,7,9

(C) 2,4,5,7

(D) 3,6,7,9

(E) 3,7,8,9

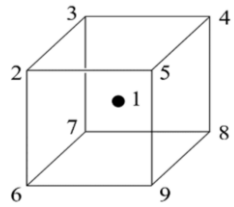


圖 4

（109 年指考 11）

Teacher: Silicon crystal (Si) is the main material in semiconductors, and its bonding is sp^3 hybrid orbitals. What are the positions of the other Si atoms when the center is at position 1?

Student: The shape of sp^3 hybrid orbitals is a regular tetrahedron, so the possible positions for Si are (3, 5, 6, 8) or (2, 4, 7, 9).

Teacher: Very good! So, the answer to this question is option (B).

老師：矽晶（Si）是半導體中的主要材料，其鍵結方式為 sp^3 混成軌域，請問中心為 1 其餘 Si 的位置為何？

學生：sp^3 混成軌域的形狀為正四面體，因此 Si 可能的位置為(3、5、6、8)或是(2、4、7、9)。

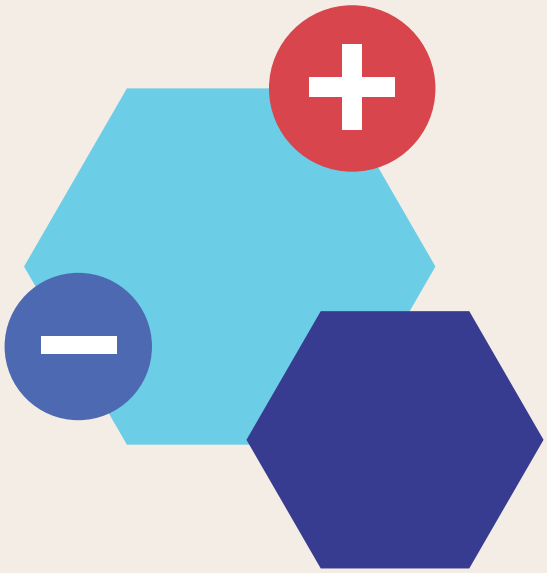
老師：很好！所以這一題的答案為(B)選項。

國內外參考資源 More to Explore

Ward's Science featuring Ward's World 提供國中及高中年齡層學生及教師使用，也有影片。也有其他自然科。 https://wardsworld.wardsci.com/chemistry	
Middle School Chemistry 提供國中教師完整教學指引，學習單，教學影片。 https://www.middleschoolchemistry.com/	
American Association of Chemistry Teachers 美國教師化學協會，提供個階段教師資源分享。 https://teachchemistry.org/	
Khan Academy 可汗學院，有分年級的化學教學影片及問題的討論。 https://www.khanacademy.org/	
Interactive Simulations, University of Colorado Boulder 互動式電腦模擬，除了化學，還有其他自然科。 https://phet.colorado.edu/	

自然領域雙語教學資源手冊：化學科英語授課用語
[選修化學(IV)]
A Reference Handbook for Senior High School Bilingual Teachers in the Domain of Natural Sciences (Chemistry): Instructional Language in English
[Elective Chemistry (IV)]

- 研編單位：國立彰化師範大學雙語教學研究中心
- 指導單位：教育部師資培育及藝術教育司
- 撰稿：黃心宜、林品融
- 語言諮詢：龔慧懿
- 綜合規劃：曾松德
- 排版：吳依靜
- 封面封底：JUPE Design



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