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(II)〕

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 原子構造 ★
Atomic Structure

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■ 前言 Introduction

本章首先介紹氫原子光譜，並藉由拉塞福原子模型的矛盾點及修正，引導學生認識波耳的氫原子模型，了解電子在原子核外的運動情形，接著介紹原子軌域及電子組態的表示法，使學生熟悉遞建原理、包立不相容原理及洪德定則，更進一步讓學生了解光譜和軌域能階的關係。最後說明現代週期表依原子序的大小排列而成，深入了解週期表中各元素原子半徑、游離能及電負度的規律性變化。

1-1 氫原子光譜
Hydrogen Atom Spectrum

■ 前言 Introduction

在本小節中，教師介紹生活中常見的各種電磁波，探討其波長，頻率與能量的關係，並分辨連續光譜和線光譜的不同，更進一步藉由芮得柏方程式計算各系列譜線間頻率的關係。

本節與下一節的單字將會影響學生學習光譜相關知識，因此在進入產出階段前須讓學生多做練習，句型則是讓學生認識光譜在生活中的應用，期望學生課後能順利辨別並描述生活中的電磁波。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electromagnetic waves	電磁波	ultraviolet light	紫外線
speed of light	光速	visible light	可見光
wavelength	波長	infrared	紅外線
frequency	頻率	microwave	微波
continuous spectrum	連續光譜	radio waves	無線電波
line spectrum	線光譜	Planck constant	普朗克常數
photon	光子	the Rydberg equation	芮得柏方程式
absorption spectrum	吸收光譜	emission spectrum	發射光譜

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

❶ _____, the _____ of which _____.

例句：Visible light, **the** wavelength **of which** is between 400 and 700 nanometers, is visible to the naked eye.

肉眼可辨識的可見光，其波長範圍在 400 到 700 奈米之間。

❷ ____ account for _____.

例句：Electromagnetic waves, invisible to the human eye, **account for** the majority on the other hand.

人眼無法見的電磁波則佔大部份。

❸ Since _____.

例句：**Since** the gas particles are heated or placed in the electric tube, the light excited by the high-voltage electricity is passed through the prism, and its spectrum is composed of discontinuous light.

當氣體粒子受熱或放在電管中時通入高壓電所激發出的光，透過三稜鏡折射後，其光譜是由不連續的光線組成。

❹ _____ by means of _____.

例句：Different atoms have different emission spectra, and these spectral bright lines represent light of specific wavelengths, so the types of elements can be identified **by means of** the emission spectra of atoms.

不同的原子具有不同的發光光譜，這些光譜亮線代表特定波長的光，因此可以藉由原子的發射光譜來鑑定元素的種類。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能計算電磁波的波長、頻率和能量，並藉由芮得柏方程式計算各系列譜線間頻率。

Students can come up with the wavelength, frequency, and energy of electromagnetic waves, and calculate the frequency between each series of spectral lines with the Rydberg equation.

❧ 例題講解 ☙

例題一

說明：學生能藉由光源的波長計算光能。

Students can calculate the energy of light from the wavelength of the light source.

A commercially available nano photocatalyst of a certain brand contains nano-sized titanium dioxide (TiO_2). When it is irradiated with a light source with a wavelength of less than 380 nm, the titanium dioxide can be sterilized. What is the energy in kJ/mol of the light with a wavelength of 380 nm?

市售某廠牌的奈米光觸媒含有奈米尺寸的二氧化鈦（TiO_2），將其照射波長小於 380 nm 的光源時，可使二氧化鈦發揮殺菌的功能。試求此波長 380 nm 的光線其能量為多少 kJ/mol？

（南一版 110 下課本（選修化學 II）第一章 第 9 頁 練習 1）

Teacher: The solution to this question is to calculate of light energy with a wavelength of 380 nm. What is the formula for light energy that we have learned?

Student: $E = h\nu$.

Teacher: That's right, can we know the frequency of this light source from the statement of the question?

Student: We couldn't tell. We need to calculate frequency with $c=\lambda\times\nu$.

Teacher: That's right, we use this formula to transpose as $\nu=c/\lambda$, so we can know what the frequency of the light source with a wavelength of 380 nm is …?

Student: $3.0\times10^{8} / 380\times10^{-9} = 7.90\times10^{14}$

Teacher: Great, how much light energy can be calculated after bringing the calculated frequency of the light source into the formula of light energy?

Student: $E = h\nu = 6.626\times10^{-34} \times 7.90\times10^{14} = 5.23\times10^{-19}$ J

Teacher: It's great, but pay attention to the units. The unit we calculated is J, and the question is asking for kJ/mol, which is "how many kilojoules of energy per mole," so how do we convert it?

Student: It should be divided by 1000 to convert to kJ, and multiplied by the number of moles, so the answer is

5.23×10^{-19} J $\times$ 6.02×10^{23} mol$^{-1}\times10^{-3}$ kJ/J = 315 kJ/mol.

老師： 這題的目的在計算波長 380 nm 的光能為多少 kJ/mol，我們學過光能的公式為何呢？

學生： $E=h\nu$。

老師： 沒錯，我們能夠從題目得知此光源的頻率嗎？

學生： 不知道，需要用 $c=\lambda\times\nu$ 計算頻率。

老師： 沒錯，我們利用這個公式移項為 $\nu=c/\lambda$，所以可以知道波長 380 nm 的光源頻率為多少？

學生： $3.0\times10^{8} / 380\times10^{-9} = 7.90\times10^{14}$。

老師： 很棒，再來將計算出的光源頻率帶入光能的公式就可以算出光能為多少？

學生： 用 $E = h\nu = 6.626\times10^{-34} \times 7.90 \times10^{14} = 5.23\times10^{-19}$ J。

老師： 很棒，但要注意單位，我們計算出來的單位是 J ，題目則是要求 kJ/mol，也就是每莫耳多少千焦耳的能量，所以我們該怎麼換算呢？

學生： 除以 1000 換算成 kJ，並乘以莫耳數，所以答案是

5.23×10^{-19} J $\times$ 6.02×10^{23} mol$^{-1}\times10^{-3}$ kJ/J = 315 kJ/mol.。

例題二

說明：學生能藉由芮得柏公式推算譜線之波長及頻率。

Students can calculate the wavelength and frequency of spectral lines by using Rydberg's formula.

Estimate the wavelength and frequency of the second spectral line of the Balmer system according to the Rydberg formula.

根據芮得柏公式估算巴耳末系的第 2 條譜線之波長及頻率。

（南一版 110 下課本（選修化學 II）第一章 第 9 頁 練習 2）

Teacher: For this question, we should first know how much n_L and n_H are in the second line of the Balmer system.

Student: The n_L of the Balmer system is 2, and the n_H of the second spectral line is 4.

Teacher: That's right. Then you can use the Rudberg formula to calculate the frequency.

Student: $\frac{1}{\lambda} = R \times \left(\frac{1}{{n_l}^2} - \frac{1}{{n_H}^2}\right)$.

Teacher: That's right. Then replace n_L with 2 and n_H with 4. Can you tell me how much the wavelength is?

Student: $\frac{1}{\lambda} = 1.097\times10^{-2}\times\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$. Therefore, λ = 486.2 nm.

Teacher: It's great. What formula should be used to calculate the frequency of light?

Student: The formula of the speed of light. ($c = \lambda\times\nu$) .

Teacher: That's right. We can also learn from the formula that $\nu=c/\lambda$, and what frequency can be obtained by substituting the calculated wavelength?

Student: $3.0\times10^{8} / 486.2 \times 10^{-9} = 6.167\times10^{14}$.

Teacher: Great, so what is the wavelength and frequency of the second spectral line of the Balmer system?

Student: The wavelength is 486.2 nm, and the frequency is 6.167×10^{14} (s^{-1}) .

老師： 這一題我們要先知道巴耳末系的第 2 條譜線的 n_L 和 n_H 為多少？

學生： 巴耳末系的 n_L 是 2，第 2 譜線的 n_H 為 4。

老師： 沒錯，再來使用芮得柏公式就可以計算頻率了，我們學過芮得柏公式為何呢？

學生：$\frac{1}{\lambda} = R \times \left(\frac{1}{{n_l}^2} - \frac{1}{{n_H}^2}\right)$。

老師：沒錯，接著把 $n_L = 2$ 和 $n_H = 4$ 代入，計算波長為多少呢？

學生：$\frac{1}{\lambda} = 1.097\times10^{-2}\times\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$，所以 $\lambda = 486.2$ nm。

老師：非常棒，再來頻率推算光的頻率要用什麼公式呢？

學生：光速的公式 $c = \lambda \times \nu$。

老師：沒錯，利用這個公式移項為 $\nu = c/\lambda$，將計算出來的波長代入，可以得到頻率為多少呢？

學生：$3.0\times10^{8} / 486.2 \times 10^{-9} = 6.167\times10^{14}$。

老師：很棒，所以巴耳末系的第 2 條譜線之波長及頻率為多少呢？

學生：波長是 486.2 nm，頻率是 6.167×10^{14}（s^{-1}）。

1-2 波耳氫原子模型
Bohr Model of the Hydrogen Atom

■ 前言 Introduction

本章藉由國中所學的拉塞福的矛盾點及修正，進而介紹波耳的氫原子模型以及能階的概念，讓學生了解原子結構的真正面目，為了讓學生能觀察出矛盾點並修正，學生需要學習與轉變有關的轉折語與片語，以順理闡述過去學習內容與新的學習內容之矛盾點與改變。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
energy level	能階	ionization energy	游離能
ground state	基態	electronic transition	電子躍遷
excited state	激發態		

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

❶ However, _____.

例句：**However,** according to Rutherford's model of the atom, there is no specific limit to the amount of energy an electron can have.

然而根據拉塞福的原子模型，電子可以擁有的能量並沒有特定的限制。

❷ _____from _____ to _____.

例句：When electrons “jump” **from** a high energy level **to** a lower energy level, if energy is released in the form of light, an emission spectrum of a specific wavelength will be produced.

當電子從高能階躍遷至較低能階時，若以光的形式釋放能量，將產生特定波長的發射光譜。

❸ Conversely, _____.

例句：**Conversely,** if electrons absorb light of a specific wavelength, they can promote from a lower energy level to a higher energy level.

反之，若電子吸收特定波長的光，可由低能階躍遷至較高能階。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能經公式推算氫原子各能階的能量大小，並藉由電子在不同能階間的躍遷說明氫原子光譜。

Students can calculate the energy of each energy level of the hydrogen atom, and explain the spectrum of the hydrogen atom through the transition of electrons between different energy levels.

例題講解

例題一

說明：學生能認識電子躍遷和能階的概念，並判斷各系列譜線的波長關係。

Students can understand the concepts of electronic transition and energy level, and judge the wavelength relationship of each series of spectral lines.

In the spectrum of hydrogen atoms, the wavelengths of the first and second bands in the ultraviolet region are λ_1 and λ_2, while the wavelength of the first band in the visible light region is λ_3. Which of the following relational expressions is correct?

(A) $\lambda_1 + \lambda_2 = \lambda_3$

(B) $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

(C) $\boldsymbol{\frac{1}{\lambda_1} + \frac{1}{\lambda_3} = \frac{1}{\lambda_2}}$

(D) $\lambda_1 + \lambda_3 = \lambda_2$

(E) $\lambda_1\lambda_2 = \lambda_3$

氫原子光譜中紫外光區第 1 條和第 2 條的波長為 λ_1、λ_2，而可見光區第一條的波長為 λ_3，則下列關係式何者正確？

(A) $\lambda_1 + \lambda_2 = \lambda_3$

(B) $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

(C) $\boldsymbol{\frac{1}{\lambda_1} + \frac{1}{\lambda_3} = \frac{1}{\lambda_2}}$

(D) $\lambda_1 + \lambda_3 = \lambda_2$

(E) $\lambda_1\lambda_2 = \lambda_3$

（南一版 110 下課本（選修化學 II）第一章 習題 單選題第 7 題）

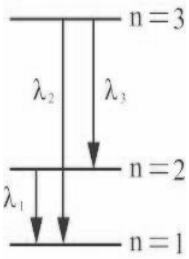
Teacher: For this question, we must first know how much n_L is in the ultraviolet region.

Student: n_L in the ultraviolet region is 1.

Teacher: That's right, what kind of energy level shifts are the first and second in the ultraviolet region?

Student: The first is that n=2 releases energy to n=1, and the second is that n=3 releases energy to n=1.

Teacher: Great, we can draw a graph like this.



How much is n_L in the visible light region?

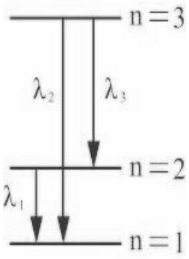
Student: n_L=2 in the visible region.

Teacher: That's right, what kind of energy level transfer is the first item in the visible light region?

Student: The first one is that n=3 releases energy to n=2.

Teacher: Great, if you want to draw an energy level diagram, how should you draw it?

Student:



Teacher: Great, As we know, energy is inversely proportional to wavelength. Therefore, if we use energy to represent it, we get E1 + E3 = E2. How should the energy relationship of these three wavelengths be expressed?

Student: $\frac{1}{\lambda_1}+\frac{1}{\lambda_3}=\frac{1}{\lambda_2}$

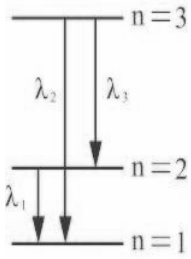
老師： 這一題我們要先知道紫外光區 n_L 為多少呢？

學生： 紫外光區 $n_L=1$

老師： 沒錯，紫外光區第 1 條和第 2 條分別是何種能階的轉移呢？

學生： 第 1 條是 n＝2 釋放能量到 n＝1，第 2 條是 n＝3 釋放能量到 n＝1。

老師： 很棒，我們可以畫出這樣的圖。



再來可見光區 n_L 為多少呢？

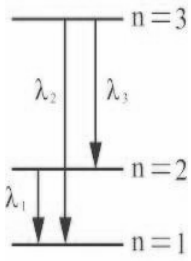
學生：　可見光區的 $n_L=2$。

老師：　沒錯，可見光區第 1 條是何種能階的轉移呢？

學生：　第 1 條是 n＝3 釋放能量到 n＝2

老師：　很棒，如果要畫成能階圖應該怎麼畫呢？

學生：



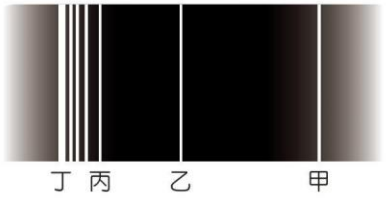
老師：　非常棒，而我們知道能量會和波長成反比因此如果使用能量來表示，我們會得到 $E_1 + E_3 = E_2$，則請問這三條波長的能量關係應該怎麼表示呢？

學生：　$\frac{1}{\lambda_1}+\frac{1}{\lambda_3}=\frac{1}{\lambda_2}$

例題二

說明：能讓學生了解波以耳定律中壓力與體積的關係。
Students can understand the relationship between pressure and volume in Boyle's law.

The figure below shows the spectral lines of the Balmer series. Jia (甲) and Ding (丁) are the rightmost and leftmost spectral lines in this series, respectively. Which of the following related statements is correct?



(A) Frequency size: Jia (甲) >Yi(乙)>Bing(丙)>Ding (丁).
(B) Jia (甲) is the spectral line obtained by reducing n=∞ to n=2.
(C) The longest wavelength spectral line is Jia (甲).
(D) The Leman series spectral line should be on the right side of Jia (甲).
(E) The energy of Ding (丁) is equal to the ionization energy of the hydrogen atom.

下圖是巴耳末系列譜線，甲與丁分別是此系列中最右與最左邊的譜線，下列相關敘述何者正確？
(A) 頻率大小：甲＞乙＞丙＞丁。
(B) 甲為由 n＝∞降到 n＝2 所得到的譜線。
(C) 波長最長的譜線為甲。
(D) 來曼系列譜線應在甲的右邊。
(E) 丁的能量等於氫原子的游離能。

（翰林版 110 下課本（選修化學 II）第一章 第 47 頁 習題 6）

Teacher: For this question, we need to look at the graph to judge the relationship between the spectral lines. First, we have to determine what kind of energy level transfer of spectral line jia 甲.
Student: It is the line where n=3 releases energy to n=2.
Teacher: That's right, it is the first spectral line of the Balmer series, so what is the correct order of the wavelengths?
Student: Jia 甲, yi 乙, bing 丙, ding 丁.

Teacher: Great, so should the frequency be directly or inversely proportional to the wavelength?

Student: Inversely proportional, so the order of frequency is ding 丁, bing 丙, yi 乙, and then jia 甲.

Teacher: So which side of the Balmer series should the spectral line of the Lyman series be?

Student: Left.

Teacher: Great, so the ionization energy of the hydrogen atom refers to the energy required for the transfer of electrons from which energy level?

Student: n=1 absorbs energy to n=∞.

Teacher: That's right, so can the spectral lines of ion energy be seen from the Balmer series of spectral lines?

Student: No, because the Balmer series of spectral lines are all spectral lines reduced from high energy level to n=2.

老師： 這一題我們要看圖判斷各譜線間的關係，首先判斷甲是何種能階的轉移的譜線呢？

學生： 是 n＝3 釋放能量到 n＝2 的譜線。

老師： 沒錯，也就是巴耳末系列的第一條譜線，所以波長的大小順序為何呢？

學生： 甲＞乙＞丙＞丁。

老師： 很棒，那頻率應該跟波長成正比還是反比呢？

學生： 反比，所以頻率大小順序是甲<乙<丙<丁。

老師： 那麼來曼系列譜線應該在巴耳末系列的哪邊呢？

學生： 左邊。

老師： 非常棒，那氫原子的游離能是指電子從何種能階的轉移所需的能量呢？

學生： n＝１吸收能量到 n＝∞。

老師： 沒錯，所以從巴耳末系列譜線可以看到游離能的譜線嗎？

學生： 不行，因為巴耳末系列譜線都是由高能階降至 n＝2 的譜線。

1-3 原子軌域
Atomic Orbital

■ 前言 Introduction

本小節教師介紹電子在核外的分佈情形，藉由量子數讓學生認識原子軌域的形狀及軌域的方向，並比較氫原子及多電子原子軌域間能量的差異。

本小節語言學習有兩大重點：利用「描述關係」與「描述用途」的英文句型讓學生說出何謂軌域、三個量子數與能階；再者，學生可利用原子軌域常見的句型，來推論量子數與軌域存在的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
orbital	軌域	magnetic quantum number	磁量子數
principal quantum number	主量子數	spin quantum number	自旋量子數
angular momentum quantum number	角動量量子數	electronic cloud	電子雲
shell	殼層	electron cloud; electron density map	電子雲；電子密度圖
volatility	波動性	Subshell	副殼層

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

❶ _____be used to_____. = _____be used for _____.

例句：The principal quantum number **is used to** indicate the shell in which the orbital is located.

= The principal quantum number **is used for** indicating the shell in which the orbital is located.

主量子數用來表示軌域所在的殼層。

❷ _____ be related to _____. =_____ be relevant to _____.

例句：Because of the interaction between electrons and atomic nuclei and between electrons and electrons, the energy level of the multi-electron atomic orbital **is related** not only **to** the principal quantum number but also to the angular momentum quantum number.

= Because of the interaction between electrons and atomic nuclei and between electrons and electrons, the energy level of the multi-electron atomic orbital **is relevant** not only **to** the principal quantum number but also to the angular momentum quantum number.

多電子原子軌域的能階，由於電子與原子核之間及電子與電子之間的交互作用，其能量不僅與主量子數有關，也與角動量量子數有關。

❸ When _____ and _____, _____ orbital exist.

例句：**When** the principal quantum number n=3 **and** the angular quantum number l = 0, 1, and 2, only 3s, 3p, and 3d **orbital exist**.

主量子數 n = 3 時，角量子數 l = 0、1、和 2，只有 3s、3p、3d 軌域存在。

❹ The principal quantum number_____ indicates that _____.

例句：**The principal quantum number** n=5 **indicates that** there are five orbitals with different shapes, namely 5s, 5p, 5d, 5f, and 5g.

主量子數 n＝5 表示有 5 種不同形狀的軌域，分別是 5s、5p、5d、5f、和 5g。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能分辨原子軌域的種類及形狀，並比較氫原子及多電子原子軌域能階高低。

Students can distinguish the types and shapes of atomic orbitals, and compare the atomic orbital energy levels of hydrogen atoms and multi-electron atoms.

❧ 例題講解 ☙

例題一

說明：學生能分辨原子軌域的種類，並比較能階高低。

Students can distinguish the types of atomic orbital and compare the energy levels.

The principal quantum number n=5. Which of the following statements are correct?

(A) It can hold up to 18 electrons.

(B) There are 5 kinds of subshells.

(C) The 5s orbital is a spherical orbital.

(D) For iodine atom, the order of energy order: 5s ＜ 5p.

(E) For helium ion (He+), the order of energy order: 5s ＜ 5p.

主量子數 n＝5，下列相關敘述哪些正確？

(A) 最多可以容納 18 個電子。

(B) 共有 5 種副殼層。

(C) 5s 軌域為球形的軌域。

(D) 對碘原子而言，能階大小順序：5s＜5p。

(E) 對氦離子（He^+）而言，能階大小順序：5s＜5p。

（來源：翰林版 110 下課本（選修化學 II）第一章 第 47 頁 習題 8）

Teacher: The purpose of this question is to understand the characteristics of the shell with the principal quantum number of 5. First of all, how many different shapes of orbitals does the principal quantum number of 5 represent?

Student: The principal quantum number n=5 indicates that there are five orbitals with different shapes, namely 5s, 5p, 5d, 5f, and 5g.

Teacher: That's correct. What shape is the 5s orbital?

Student: The s orbital is spherical.

Teacher: Yes, what is the mathematical relationship between shell n and the maximum number of electrons?

Student: The maximum number of electrons that can be accommodated = $2n^2$.

Teacher: Great, so how many electrons can the principal quantum number n = 5 hold?

Student: 50.

Teacher: Next, let's first judge whether the iodine atom of option (D) is a single-electron or multi-electron atom.

Student: A multi-electron atom.

Teacher: How do we judge the energy level of multiple-electron atomic orbitals?

Student: The energy level of a multi-electron atomic orbital is determined by the sum (n+ℓ) of the principal quantum number and the angular momentum quantum number.

Teacher: It's great, so which energy order is higher for 5s or 5p of iodine atoms?

Student: 5s n+ℓ=5, 5p n+ℓ=6, so 5p has a larger energy order.

Teacher: That's correct. Then let's first determine whether He^+ is a single-electron or multi-electron atom in the (E) option.

Student: A single-electron atom.

Teacher: How do we determine the energy level of a single-electron atom orbital?

Student: Compare the principal quantum numbers directly.

Teacher: Great, so which energy order is higher for helium ion 5s or 5p?

Student The principal quantum numbers of 5s and 5p are both 5, so they are the same.

老師： 這一題目的在了解主量子數為 5 的殼層的特徵，首先主量子數為 5 表示有幾種不同形狀的軌域呢？

學生： 主量子數 n＝5 表示有 5 種不同形狀的軌域，分別是 5s、5p、5d、5f、5g。

老師： 答對了，5s 的軌域是什麼形狀呢？

學生： s 軌域為球型。

老師： 沒錯，那麼殼層 n 與最多容納之電子數之間有什麼數學關係式存在？

學生： 最多容納電子數＝$2n^2$。

老師： 很棒，所以主量子數 n＝5 最多可以容納幾個電子呢？

學生： 50 個。

老師： 接著(D)選項先判斷碘原子是單電子還是多電子的原子呢？
學生： 多電子的原子。
老師： 我們該如何判斷多電子原子軌域的能階大小呢？
學生： 多電子原子軌域的能階由主量子數與角動量量子數的和（n＋ℓ）判斷。
老師： 很棒，所以碘原子 5s 和 5p 哪個能階大呢？
學生： 5s 的 n＋ℓ＝5，5p 的 n＋ℓ＝6，所以是 5p 的能階比較大。
老師： 答對了，接著(E)選項先判斷 He^{+}是單電子還是多電子的原子呢？
學生： 單電子的原子。
老師： 我們該如何判斷單電子原子軌域的能階大小呢？
學生： 直接比較主量子數。
老師： 很棒，所以氦離子 5s 和 5p 哪個能階大呢？
學生： 5s 和 5p 的主量子數都是 5，所以一樣大。

例題二

說明：學生能判斷原子軌域的合理性。
Students can determine the plausibility of atomic orbitals.

Which of the following atomic orbitals does not exist?
(A) 2p
(B) 2d
(C) 3p
(D) 3f
(E) 4d

下列哪些原子軌域不存在？
(A) 2p　**(B) 2d**　(C) 3p　**(D) 3f**　(E) 4d

（南一版 110 下課本（選修化學 II）第一章 第 29 頁 練習 5）

Teacher: The purpose of this question is to determine whether the principal quantum number and its orbital exist. First, what kinds of orbitals do the main quantum number n=2 have?
Student: Two, 2s and 2p.
Teacher: That's correct, then what kinds of orbitals do the principal quantum number n=3 have?
Student: Three, 3s, 3p, and 3d.

Teacher: Great, what kinds of orbitals do the principal quantum number n=4 have?

Student: Four, 4s, 4p, 4d, and 4f.

Teacher: Excellent, so which electronic tracks do not exist in the options?

Student: 2d and 3f do not exist.

老師： 這一題目的是判斷主量子數和其軌域是否存在，首先主量子數 n＝2 有哪幾種軌域呢？

學生： 兩種，2s 和 2p。

老師： 沒錯，那麼主量子數 n＝3 有哪幾種軌域呢？

學生： 三種，3s、3p、3d。

老師： 很棒，那麼主量子數 n＝4 有哪幾種軌域呢？

學生： 四種，4s、4p、4d、4f。

老師： 非常棒，所以選項中哪幾個電子軌域不存在呢？

學生： 2d 和 3f 不存在。

1-4 電子組態
Electronic Configuration

■ 前言 Introduction

在本小節中，教師引導帶學生探討電子在軌域的分佈以及規律，進而用電子組態去了解不同元素的性質。

為了讓學生描述電子在軌域的分佈以及規律，學生需要學習軌域上電子是否成對的句型，並使用「涉及」、「遵守」或轉折語來描述是否遵守多電子原子的電子填入軌域時的遞建原理、包立不相容原理及洪德定則等三個規則。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electron configuration	電子組態	Aufbau principle	遞建原理
Pauli exclusion principle	包立不相容原理	Hund's rule	洪德定則
ground state	基態	inner shell	內殼層；核層
valence shell	價殼層	valence electron	價電子
main group element	主族元素	transition element	過渡元素
valence orbital	價軌域	excited state	激發態

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

❶ _____ refer to _____.

例句：Electronic configuration **refers to** the electronic arrangement of the most stable ground-state atoms.

電子組態指的是最穩定之基態原子的電子排列方式。

❷ _____ comply with _____.

例句：When the electrons of multi-electron atoms fill the orbital, they must **comply with** the A Aufbau principle, the Pauli exclusion principle, and Hund's rule.

多電子原子的電子填入軌域時，必須遵守遞建原理、包立不相容原理和洪德定則。

❸ _____, otherwise _____.

例句：The electronic configuration cannot violate the Pauli exclusion principle, **otherwise** it does not exist.

電子組態不可違反包立不相容原理，否則不存在。

❹ There is a pair of electrons in _____ orbital.

例句：**There is a pair of electrons in** 1s **orbital**.

1s 軌域有一對成對電子。

❺ There is an unpaired electrons in the _____ orbital.

例句：**There is an unpaired electrons in the** 2s **orbital**.

2s 軌域有一個不成對電子。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

After this lesson, students should be able to know:

學生能了解電子組態的表示方式、意義及基本的三個原則。

Students can understand the expression, meaning and three basic principles of electron configuration.

❧ 例題講解 ☙

例題一

說明：學生能利用電子組態的三個基本原則來判斷原子的穩定性。

Students can use the three basic principles of electron configuration to judge the stability of atoms.

The electronic configurations of a and b atoms are as follows: a：$1s^2 2s^2 2p^6 3s^1$。b：$1s^2 2s^2 2p^6 3d^1$. Which of the following related statements are correct?

(A) a is the main group element

(B) a and b are different elements

(C) a is more stable than b

(D) b violates Hund's rule

(E) a is the ground state.

a、b 兩個原子的電子組態如下：a：$1s^2 2s^2 2p^6 3s^1$。b：$1s^2 2s^2 2p^6 3d^1$。下列相關敘述，哪些正確？

(A) a 為主族元素

(B) a、b 為不同元素

(C) a 比 b 穩定

(D) b 違反洪德定則

(E) a 為基態。

（翰林版 110 上課本（選修化學 II）第一章 第 30 頁 練習 1-5）

Teacher: In class, we learned what three principles should be followed to write the electron configuration of atoms.

Student: Aufbau principle, Pauli exclusion principle, and Hund's rule.

Teacher: Yes. Which family of elements does option (A) require us to judge? What should we do?

Student: A has 11 electrons and the valence shell is $3s^1$, so it can be determined that Na is in the main group element. Therefore, the (A) option is correct.

Teacher: Then (B) asks whether a and b are different elements. How should we judge?

Student: a and b are the same element because the total number of electrons is 11 electrons. Only the b atom is in an excited state, while a atom is in a ground state.

Teacher: Well, what principle does it violate to say that the electronic configuration filled with b atom does not follow the low energy level to the high energy level?

Student: Aufbau principle.

Teacher: Yes, it is not a violation of Hund's rule. So what are the correct options for this question?

Student: (A)(C)(E).

老師： 在課堂中我們學過，要寫出原子的電子組態需要符合哪三個原則來填入？

學生： 遞建原理、包立不相容原理、洪德定則。

老師： 沒錯。那(A)選項要判斷是哪一族的元素?我們該怎麼做？

學生： a 有 11 個電子，且價殼層為 $3s^1$ 因此可以判斷為主族元素中的 Na，因此(A)選項正確。

老師： 那(B)選項問 a、b 是否為不同元素，我們該如何判斷？

學生： a 和 b 為相同元素，因爲總電子數都是 11 個電子，只是 b 原子為激發態，而 a 原子為基態。

老師： 很好，那我們說 b 原子這樣填入的電子組態沒有按照低能階到高能階是違反了哪一個原則？

學生： 遞建原理。

老師： 沒錯，而並非是違反了洪德定則。因此此題正確的選項有哪些？

學生： (A)(C)(E)。

例題二

說明：學生能利用電子組態來判斷出元素週期表中的元素。

Students can use electron configuration to judge the elements in the periodic table.

When an artificial element is in the ground state, the configuration of $7p^6$ can be obtained by filling in the last electron. According to the periodic table of elements, which statements about this element are correct?

(A) The atomic number is 118

(B) Similar in nature to blunt gas

(C) Non-radioactive passive gas elements

(D) Its electronic configuration is$[Rn]6d^{10}7s^27p^6$

(E) The number of protons in a positive divalent ion is 116

有一人造元素在基態時，填入最後的一個電子可得具有 $7p^6$ 的組態，依據元素週期表，有關該元素的敘述，哪些正確？

(A) 原子序為 118

(B) 性質與鈍氣相似

(C) 不具有放射性的鈍氣元素

(D) 其電子組態為$[Rn]6d^{10}7s^27p^6$

(E) 正二價離子的質子數為 116

（龍騰版 110 上課本（選修化學 II）第一章 第 31 頁 例題 1-8）

Teacher: According to the question, the last electron of this element in the ground state can have a configuration of $7p^6$, which means that the valence electron configuration of this element is $7s^27p^6$, so we can know which period of the element it is, and which group it is. What about the elements?

Student: It is the noble gas element of the seventh period.

Teacher: That's right. So we can calculate the atomic number of this artificial element by adding the atomic number r of the noble gas in the sixth period e and the 32 elements that can be filled in the seventh period. So what is the atomic number of this element?

Student: The atomic number r of Rn is 86, plus 32, which is 118, so the atomic number of this element is 118.

Teacher: Great, so we can deduce how the electronic configuration of this element should be filled in.

Student: $[Rn]5f^{14}6d^{10}7s^{2}7p^{6}$.

Teacher: Yes, so the option (D) is wrong, and the electronic configuration is missing $5f^{14}$.

Teacher: Is this element radioactive?

Student: Yes, because man-made elements are radioactive.

Teacher: Wonderful. And option (E) says that the number of protons of positive divalent ions is 116, is it correct?

Student: Wrong, because the gain and loss of electrons will not affect the number of protons, so the number of protons is also 118.

Teacher: That's correct, so the answer is (A)(B).

老師： 由題目說此元素在基態時最後的一個電子可得具有 $7p^{6}$ 的組態，表示說此元素的的價電子組態為 $7s^{2}7p^{6}$，因此我們可以知道這是第幾週期的元素，以及是哪一族的元素呢？

學生： 為第七週期的鈍氣元素。

老師： 沒錯，那因此我們可以藉由第六週期鈍氣的原子序再加上要填入第七週期可以填入的 32 個元素，如此一來我們就可以推算出此人造元素的原子序，因此此元素的原子序為多少？

學生： Rn 的原子序為 86，再加上 32，即為 118，因此此元素的原子序為 118。

老師： 很好，因此我們可以推斷出此元素的電子組態該如何填寫？

學生： $[Rn]5f^{14}6d^{10}7s^{2}7p^{6}$。

老師： 沒錯，因此(D)選項錯了，電子組態少寫了 $5f^{14}$。

老師： 那此元素是否有放射性？

學生： 有，因爲人造元素都會有放射性。

老師： 很好。而(E)選項說正二價離子的質子數為 116 是否正確？

學生： 錯誤，因為電子的得失不會影響到質子的數目，因此質子數一樣是 118 個。

老師： 對，因此答案選(A)(B)。

1-5 元素性質的週期性
Periodicity of Elemental Properties

■ 前言 Introduction

在本小節教師利用前一小節所學的電子組態的微觀概念，引導學生討論元素週期表中的原子半徑及離子半徑、游離能、電負度。

在語言方面，本小節的教學重點在於表達比較大小，並利用轉折連結詞或對等連接詞來描述元素週期表中的原子半徑及離子半徑、游離能、電負度之間的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
ionization energy	游離能	electronegativity	電負度
van der Waals radius	凡得瓦半徑	nonpolar covalent bond	非極性共價鍵
polar covalent bond	極性共價鍵	atomic radius	原子半徑

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

❶ _____ increase with _____.

例句：The atomic radius of the same group of elements **increases with** the increase of atomic number.

同一族元素的原子半徑隨原子序的增加而增加。

❷ _____ decrease with _____.

例句：The atomic radius of the same periodic element **decreases with** the increase of atomic number.

同一週期元素的原子半徑隨原子序的增加而減少。

❸ The ionization energy required to remove the valence electrons _____, and the ionization energy required to remove the inner electrons _____.

例句：**The ionization energy required to remove the valence electrons** is low, **and the ionization energy required to remove the inner electrons** increases rapidly.

移走價電子所需游離能較低，移去內層電子游離能急遽增大。

❹ _____ be distributed in _____.

例句：Those with larger electronegativity **are** usually **distributed in** the upper right corner of the periodic table; those with smaller electronegativity are in the lower left corner of the periodic table.

電負度較大者，通常分布在週期表右上角；電負度較小者則在週期表左下角。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

After this lesson, students should be able to know:

學生能了解元素性質的週期性，包括原子半徑及離子半徑，以及游離能及電負度的定義及概念。

Students can understand the periodicity of element properties, including atomic radius and ionic radius, as well as the definition and concept of ionization energy and electronegativity.

❧ 例題講解 ☙

例題一

說明：學生能了解游離能的意義及判斷不同原子的游離能大小。

Students can understand the meaning of ionization energy and judge the size of the ionization energy of different atoms.

Which of the following comparisons of the first ionization energy in each group is correct?
下列各組第一游離能大小比較，哪些正確？

(A) Na＞Mg

(B) Na＞K

(C) Li＞He

(D) F＞Li

(E) He＞Ne

（來源：翰林版 110 上課本（選修化學 II）第一章 第 40 頁 練習 1-8）

Teacher: We have learned in class that the definition of ionization energy is the energy required to remove an electron from the ground-state gas atom or ion from the outermost shell. What is the definition of the first ionization energy?

Student: It refers to the energy required to remove the first electron.

Teacher: Yes, let's first see whether the (A) option is correct.

Student: Incorrect, because both Na and Mg dissociate electrons in the 3s orbital. According to the octet, we know that the $2s^2$ electrons of Mg are filled, so it is difficult to remove electrons and the dissociation energy is high.

Teacher: Yes, option (B) is the same group of elements. We say that the greater the atomic number of the same family, the greater or smaller the required ionization energy.

Student: The smaller, so the ionization energy of Na is greater.

Teacher: Is the option (C) correct?

Student: Incorrect, because He is the element with the largest ionization energy.

Teacher: In option (D), they are elements of the same period. In option (E), they are elements of the same group. How do we judge the size of ionization energy?

Student: The elements of the same period will increase with the atomic number, and the ionization energy will decrease with the atomic number. Therefore, the (D) and (E) options are correct.

Teacher: Excellent, so the answer is (B)(D)(E).

老師： 我們在課堂學過游離能的定義是從基態的氣體原子或離子從最外層移走一個電子所需要的能量，第一游離能的定義是什麼？

學生： 指的是移走第一個電子所需要的能量。

老師： 沒錯，我們先來看(A)選項是否正確？

學生： 錯，因為 Na 及 Mg 皆游離 3s 軌域的電子，根據八隅體，我們可以知道 Mg 的 $2s^2$ 電子填滿，因此移走電子較難，游離能較高。

老師： 沒錯，(B)選項為同族的元素，我們說同族的原子序越大，所需的游離能會越大還是越小？

學生： 越小，因此 Na 的游離能較大。

老師： (C) 選項是否正確？

學生： 錯誤，因為 He 為游離能最大的元素。

老師： 而(D)選項為相同週期的元素，(E)選項為同族的元素，該如何判斷游離能大小？

學生： 同週期的元素會隨著原子序越大，游離能越大，同族則會隨著原子序越大游離能越小，因此(D)和(E)選項都正確。

老師： 很好，因此答案選(B)(D)(E)。

例題二

說明：學生能了解電負度的定義及比較出不同物質的電負度大小。

Students can understand the definition of electronegativity and compare the electronegativity of different substances.

Which of the following statements about electronegativity are correct?

(A) The electronegativity of elements of the same group increases with the atomic number.

(B) For the main group elements of the same period, the electronegativity increases with the increase of the atomic number (except for inert gas).

(C) Electronegativity is maximum in F.

(D) Those with greater electronegativity usually belong to metals; those with smaller electronegativity usually belong to nonmetals.

(E) When two atoms are covalently bonded, the shared electron pair tends to favor the less electronegativity atom.

下列關於電負度的敘述，哪些正確？

(A) 同一族的元素，電負度隨原子序之增加而增加。

(B) 同一週期主族元素，電負度隨原子序之增加而增加（鈍氣除外）。

(C) 電負度以 F 最大。

(D) 電負度越大者，通常屬於金屬；電負度越小者，通常屬於非金屬。

(E) 以共價鍵結合的兩原子，其共用電子對會傾向於電負度較小的原子。

（本題目改自龍騰版 110 課本（選修化學 II）第一章 第 41 頁 例 1-12 題）

Teacher: We know that the definition of electronegativity refers to the relative ability of intramolecular bonding atoms to attract common electron pairs, while the electronegativity of elements of the same group increases or decreases with the increase of atomic number.

Student: Decrease.

Teacher: That's correct. Is the option (B) correct?

Student: Correct, nonmetals will have greater electronegativity than metals in the same period, so electronegativity will increase with atomic number.

Teacher: What is the element with the most electronegativity?

Student: Fluorine, followed by oxygen and nitrogen.

Teacher: According to the definition of electronegativity, is it correct that the common electron pair of the two atoms with the (E) option combined by a covalent bond will tend to be the atom with lower electronegativity?

Student: Incorrect, shared electrons tend to be attracted to atoms with higher electronegativity.

Teacher: That's great. The answer is (B)(C).

老師： 我們知道電負度的定義指的是分子內鍵結原子吸引共用電子對的相對能力，而同一族的元素電負度隨原子序之增加而增加還是減少？

學生： 會減小。

老師： 沒錯，那(B)選項是否正確？

學生： 正確，同一週期中非金屬的電負度會大於金屬，因此電負度會隨原子序增加而增加。

老師： 電負度最大的元素是什麼？

學生： 氟，其次是氧再來是氮。

老師： 根據電負度定義，那(E)選項以共價鍵結合的兩原子，其共用電子對會傾向於電負度較小的原子是否正確？

學生： 錯誤，共用電子對會較於傾向電負度大的原子。

老師： 很好，因此答案選(B)(C)。

★ 主題二 化學鍵結 ★
Chemical Bonding

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■ 前言 Introduction

本章首先介紹不同原子間交互作用，常把化學鍵分為三種，包括離子鍵、共價鍵及金屬鍵，接著深入探討共價鍵的價鍵理論及極性，最後認識不同分子間也會有作用力，包括凡得瓦力與氫鍵。

2-1 化學鍵的種類
Types of Chemical Bonds

■ 前言 Introduction

此小節教師引導學生認識不同的化學鍵種類，並透過路易斯電子點式讓學生來了解離子鍵、共價鍵及金屬鍵的形成方式以及其特性。

學生將學習句型來表達不同的特性與傾向。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
chemical bond	化學鍵	bond energy	鍵能
ionic bond	離子鍵	bonding pair	鍵結電子對
covalent bond	共價鍵	lone pair	未鍵結電子對/孤電子對
metal bond	金屬鍵	covalent network solid	共價網狀固體
lattice energy	晶格能	electron sea	電子海
valence electrons	價電子	delocalized electrons	非定域電子
bond length	鍵長	alkali metal	鹼金屬
bond order	鍵級		

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

❶ _____ tend to _____.

例句：Non-metallic elements **tend to** gain electrons to form anions.
非金屬元素傾向於得到電子形成陰離子。

❷ Except for _____, _____. = Apart from _____, _____.

例句：**Except for** helium which has only two valence electrons**,** other noble gas elements have eight valence electrons.
除了氦僅有兩個價電子外，其他鈍氣元素均具八個價電子。

❸ The ____-er …, the _____-er.

例句：**The more** charges the ions carry, or **the** small**er** the ionic radius is, **the** great**er** the attractive force between anions and cations will be, and **the** strong**er** the ions bond.
離子所帶的電荷越多，或離子半徑越小時，陰離子、陽離子間的引力越大，離子鍵越強。

❹ _____ have a great impact on _____.

例句：Metal bond strength will **have a great impact on** metal properties.
金屬鍵強度會影響金屬性質。

■ 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:

學生能夠了解不同化學鍵的種類及其化合物的特性。

Students are able to understand different types chemical bonds and the properties of their compounds

❧ 例題講解 ☙

例題一

說明：學生能了解化學鍵結中鍵能的概念。

Students can understand the concept of bond energy in chemical bonds.

甲、乙、丙、丁 are four gaseous hydrogen halide molecules, and the relationship between the bond energy and bond length of their chemical bonds is shown in Figure 1. Regarding the correspondence between these four molecules and hydrogen halides, which one of the options in the table below is the most reasonable?

	甲	乙	丙	丁
(A)	HI	HBr	HCl	HF
(B)	HF	HCl	HBr	HI
(C)	HCl	HF	HBr	HI
(D)	HI	HBr	HF	HCl
(E)	HF	HI	HBr	HCl

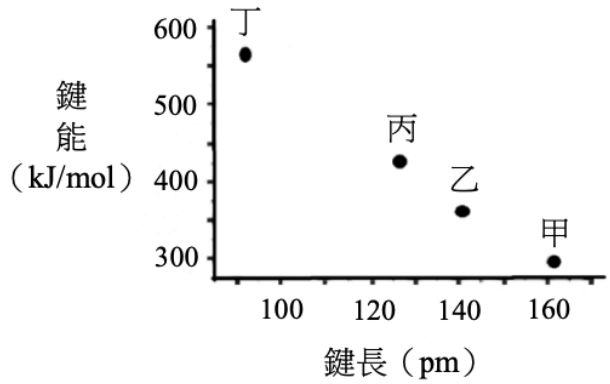


圖 1

甲、乙、丙、丁為四個氣態鹵化氫分子，其化學鍵的鍵能與鍵長的關係如圖 1 所示。針對這四個分子與鹵化氫的對應關係，下表選項中，哪一個最合理？

	甲	乙	丙	丁
(A)	HI	HBr	HCl	HF
(B)	HF	HCl	HBr	HI
(C)	HCl	HF	HBr	HI
(D)	HI	HBr	HF	HCl
(E)	HF	HI	HBr	HCl

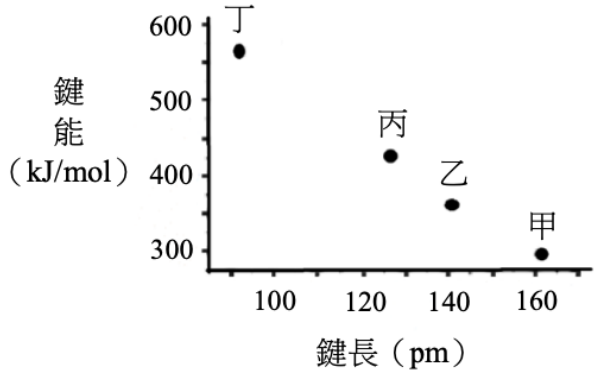


圖 1

（110 指考 第三題）

Teacher: Based on the statement of this question, first of all, which type of chemical bond does the four hydrogen halide molecules belong to?

Student: All are non-metallic elements that exist in the form of covalent bonds.

Teacher: Very good, and from Figure 1 we can see that the smaller the bond length, the greater the bond energy will be, and hydrogen halides are covalent bonds formed by single bonds, so we can use the atomic radius of different halogen elements to judge the bond length. Then what is the order of the sizes of their atomic radii?

Student: F<Cl<Br<I.

Teacher: That's right, so we now can deduce the order of the bond lengths of the four compounds?

Student: HF<HCl<HBr<HI.

Teacher: Yes, so the smaller the bond length, the greater the bond energy. Then what is the order of their bond energies?

Student: HF>HCl>HBr>HI.

Teacher: That’s correct, so which is the correct option that we should choose?

Student: (A).

老師： 從題目來看，首先我們知道四個鹵化氫分子的鍵結方式應該屬於哪一類？

學生： 都是非金屬元素，以共價鍵的鍵結形式存在。
老師： 很好，而從圖 1 我們可以知道鍵長越小，鍵能則會越大，而鹵化氫都是以單鍵形成的共價鍵，因此我們可以利用不同鹵素元素的原子半徑大小來判斷鍵長，那請問原子半徑的大小依序為何？
學生： F<Cl<Br<I。
老師： 沒錯，因此我們可以推得四種化合物鍵長大小的排序為何？
學生： HF<HCl<HBr<HI。
老師： 對，因此鍵長越小，鍵能則會越大，所以鍵能大小排序為何？
學生： HF>HCl>HBr>HI。
老師： 正確，因此根據選項的答案我們應該選誰？
學生： (A)。

例題二

說明：學生能了解金屬晶體的鍵結特性。

Students can understand the bonding properties of metal crystals.

Which of the following statements about metal crystals is/are correct?

(A) They have metallic luster.

(B) They have ductility and malleability, making them advantageous for processing.

(C) Metallic bonds in metal crystals have directionality

(D) Metal bond in metal crystals is the electrostatic attraction between metal cations and valence electrons.

(E) They are thermal insulators.

下列有關金屬晶體的敘述，哪些正確？

(A) 有金屬光澤。

(B) 具有延性及展性，故有利加工性使用。

(C) 金屬鍵具方向性。

(D) 金屬鍵是金屬陽離子與價電子之間的靜電吸引力。

(E) 為熱的絕緣體。

（南一版 110 下課本（選修化學 II）第二章 第 71 頁 例題 2-2）

Teacher: In class, we learned that metal crystals are bonded in the form of metal bonds. In solid state, a metal crystal has a sea of electrons, and therefore possesses certain characteristics. Can you name the characteristics?

Student: Thermal and electrical conductivity and excellent ductility.

Teacher: That's right, and what is the typical color and luster of metals?

Student: With a metallic luster.

Teacher: That's right, so can first tell which options are correct and which are wrong?

Student: (A) and (B) are correct, while (E) is wrong. Metals are good conductors of heat.

Teacher: Good job. How do we determine if metallic bonds have directionality? in option (C)?

Student: It can be known from the characteristics of the sea of electrons that these valence electrons are not fixed between specific cations, so they do not have directionality

Teacher: Is option (D) correct according to the characteristics of metal bonds?

Student: Correct, because the metal bond is found where atoms can easily lose electrons to form cations and free valence electrons, with electrostatic attraction between them.

Teacher: Great, so what are the correct answers to this question?

Student: (A)(B)(D).

老師： 在課堂中我們學過金屬晶體是以金屬鍵的形式鍵結，在固態時金屬金體因為有電子海，因此有哪些特性？

學生： 能導熱導電以及很好的延展性。

老師： 沒錯，且金屬的色澤通常是如何？

學生： 有金屬光澤。

老師： 沒錯，因此我們可以先判斷哪些選項正確哪些選項錯誤？

學生： (A)(B)正確(E)錯誤，金屬為熱的良導體。

老師： 正確，而(C)選項問金屬鍵是否具有方向性該如何判斷？

學生： 可以透過電子海的特性得知，這些價電子並不會固定在特定的陽離子之間，所以沒有方向性。

老師： 那(D)選項根據金屬鍵的特性是否正確？

學生： 正確，因為金屬鍵就是金屬原子很容易失去電子而形成陽離子和游離的價電子，彼此間有靜電吸引力。

老師： 很好，因此此題正確的答案為何？

學生： (A)(B)(D)。

2-2 分子的形狀
Molecular Shape

■ 前言 Introduction

此小節教師可以利用路易斯結構帶學生了解不同分子的形狀及電子分佈的情形，再藉由價殼層電子對互斥模型輔助帶學生建構分子及離子的立體形狀及預測鍵角大小。

學生在了解的過程中使用具有順序功能的句型進行討論。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Lewis structure	路易斯結構	resonance structure	共振結構
central atom	中心原子	valence shell electron pair mutual repulsion model	價殼層電子對互斥模型/ VSEPR 模型
peripheral atoms	外圍原子	bond angle	鍵角

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

❶ First, _____, and then _____, and finally _____.

例句：To make a Lewis structure, **first** we calculate the total number of valence electrons, **then** determine the central atom and peripheral atoms, **and finally** arrange the electrons to satisfy the octet rule.

當我們要製作路易斯結構時，我們要先計算價電子數總和，再決定中心原子與外圍原子最後讓價電子滿足八隅體。

❷ _____ with_____.

例句：In the resonance structure of sulfur dioxide, there is always a single bond **with** a longer bond length and a double bond with a shorter bond length.

二氧化硫的共振結構中，均有一個鍵長較長的單鍵及一個鍵長較短的雙鍵。

❸ The sum of _____.

例句：**The sum of** mutually repulsive electron clouds in the central atom of the sulfur dioxide molecule is three, and the shape formed by the electron clouds is a plane triangle.

二氧化硫分子中心原子的互斥電子雲數量為三，電子雲所形成的形狀為平面三角形。

■ 問題講解 Explanation of Problems

ଓ 學習目標 ଓ

在學習完本單元後，學生應學會以下觀念：

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

學生能透過路易斯結構了解不同分子的鍵結形式以及形狀。

Students can understand the bonding forms and shapes of different molecules through the Lewis structure.

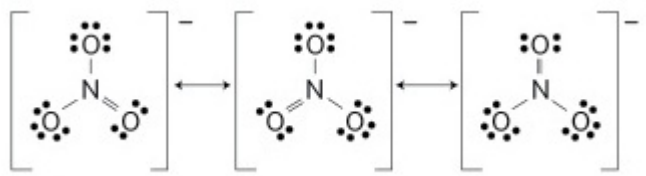
例題講解

例題一

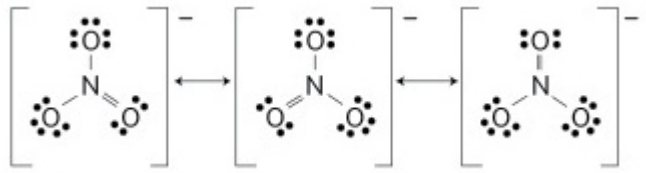
說明：學生能夠學會判斷分子的鍵級。

Students can learn how to determine the bond order of molecules.

Based on the Lewis structure of $NO3^-$, determine the bond order between N and O.



根據 NO_3^-的路易斯結構，判斷 N 與 O 之間的鍵級為多少？



（龍騰版 110 下課本（選修化學 II）第二章 例題 2-3）

（圖片來源：http://earthkart2011.blogspot.com/2012/12/resonance.html）

Teacher:	First of all, can we know the structure of this molecule from the question?
Student:	Resonance structure.
Teacher:	That's right, how was this resonant structure generated?
Student:	After drawing the Lewis structure according to the octet rule, a lone pair of electrons can be shared between N and O, so three different Lewis structures can be drawn.
Teacher:	That's right, so every resonance structure will have two single bonds and one double bond. What is the bond order then?
Student:	4/3.

老師： 首先我們由題目可以知道此分子是什麼結構？
學生： 共振結構
老師： 沒錯，此共振結構是如何產生的？
學生： 根據八隅體法則畫出路易斯結構後，有一對孤對電子可以和讓 N 和 O 能共用，因此可以畫出三個不同的路易斯結構。
老師： 沒錯，因此每一個共振結構都會有兩個單鍵及一個雙鍵，所以鍵級是多少？
學生： (1 x 2 + 2) / 3 = 4/3

例題二

說明：學生能學會判斷不同分子的鍵角。

Students can learn to judge the bond angles of different molecules.

Compare the three molecules H_2O, NH_3, and BeH_2 in terms of the order of their bond angles.

比較 H_2O、NH_3 及 BeH_2 三種分子，其鍵角的大小順序。

（來源：翰林版 110 下課本（選修化學 II）第二章 第 25 頁 練習 2-6）

Teacher: Before comparing the bond angles of the three molecules, we should first draw the Lewis structures of the three molecules. How do we draw the Lewis structures?
Student: First, calculate the total number of valence electrons: H_2O has 8, NH_3 has 8, and BeH_2 has 4. Then determine the central atom and peripheral atoms, and finally distribute the remaining valence electrons to obtain the Lewis structure.
Teacher: That's right. According to the Lewis structure drawn, we can judge the shape of the molecule by the number of mutually repulsive electron clouds, and then its bond angle. The number of mutually repulsive electron clouds includes the number of bonds between the central atom and the peripheral atoms and lone electron pairs. What are the shapes of these three molecules as a result?
Student: H_2O has two single bonds and two lone electron pairs and the number of mutually repulsive electron clouds is 4, so it is curved, and its bond angle is 104.5 degrees. NH_3 has three single bonds and one lone electron pair, and the number of mutually repulsive electron clouds. It is 4, so it is a triangular pyramid, and its bond angle is 107 degrees. BeH_2 has two single bonds, and the number of mutually repulsive electron clouds is 2, so it is straight, and its bond angle is 180 degrees.

Teacher: Great, so what is the order of the three?

Student: BeH_2>NH_3>H_2O.

老師： 在比較三種分子的鍵角大小之前，首先我們應該畫出三個分子的路易斯結構，請問該如何畫出路易斯結構？

學生： 首先要算出價電子數的總和，H_2O 為 8，NH_3 為 8，BeH_2 為 4。接著決定中心原子及外圍原子，再分配剩下的價電子，即可得路易斯結構。

老師： 沒錯，而根據畫出來的路易斯結構可以透過互斥電子雲數量來判斷分子形狀進而判斷出其鍵角，其中互斥電子雲數量包括中心原子與外圍原子的鍵結數量及孤電子對來計算。而此三種分子的形狀為何？

學生： H_2O 有兩個單鍵以及兩對孤電子對，互斥電子雲數量是 4，因此是彎曲型，其鍵角為 104.5 度；NH_3 有三個單鍵及一對孤電子對，互斥電子雲數量是 4，因此是三角錐型，其鍵角為 107 度，BeH_2 有兩個單鍵，互斥電子雲數量是 2，因此是直線形，其鍵角為 180 度。

老師： 很好，因此三者的排序為何?

學生： BeH_2>NH_3>H_2O。

2-3 價鍵理論
Valence Bond Theory

■ 前言 Introduction

此小節教師介紹 σ 鍵與 π 鍵的重疊狀況，解釋共價鍵如何形成，並認識不同鍵級與 σ 鍵、π 鍵的關係，接著透過混成軌域種類來判斷分子形狀，即價鍵理論。

在進入本小節前，可以先確定學生是否熟悉化學鍵相關的單字，在介紹共價鍵理論時，可以利用圖像加深學生對 σ 鍵和 π 鍵的記憶；句型部分，教師可引導學生用比較句了解 σ 鍵與 π 鍵的不同，並認識 sp^3、sp^2 及 sp 混成軌域的形成。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
valence bond theory	價鍵理論	hybrid orbital	混成軌域
σ bond	σ 鍵	coordinate-covalent bond	配位共價鍵
π bond	π 鍵	linear pattern	直線形
plane triangle	平面三角形	bent shaped	彎曲形
tetrahedron	四面體	triangular pyramid	三角錐

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

❶ _____be formed when _____.

例句：Bonding orbitals **are formed when** atomic orbitals overlap and share electrons to form a covalent bond.

當原子軌道重疊並共享電子形成共價鍵時，就會形成鍵結軌域。

❷ The strength of _____ is weaker than that of _____.

例句：**The strength of** a π bond **is weaker than that of** a σ bond.

π 鍵的強度比 σ 鍵弱。

❸ _____ can be obtained by mixing _____ orbitals with a _____ orbital.

例句：Four sp^3 hybrid orbitals with the same energy **can be obtained by mixing** three 2p **orbitals with a** 2s **orbital**.

以一個 2s 軌域與三個 2p 軌域混成後，可得到能量相同的四個 sp^3 混成軌域。

❹ _____, which is in group _____, forms one covalent bond to fill its octet.

例句：Fluorine, **which is in group** 7A, **forms one covalent bond to fill its octet.**

位於 7A 族的氟會形成一個共價鍵以填滿其八隅體。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能了解 σ 鍵與 π 鍵的不同，並認識 sp^3、sp^2 及 sp 混成軌域的形成。

Students can understand the difference between σ bond and π bond, and the formation of sp3, sp2, and sp hybrid orbitals.

❧ 例題講解 ☙

例題一

說明：學生能分辨 σ 鍵與 π 鍵的特徵。

Students can distinguish the characteristics of σ bonds and π bonds.

Which statement is incorrect regarding σ bonds and π bonds?

(A) A σ bond can be formed by overlapping atomic orbitals along the axis between two atomic nuclei.

(B) A π bond can be formed by parallel overlapping of two p orbitals, resulting in zero electron density along the axis between the nuclei.

(C) A σ bond exists in both single and multiple bonds, while a π bond only exists in multiple bonds.

(D) A σ bond cannot be formed between p orbitals.

(E) When a σ bond is formed, the electron density is symmetrically distributed along the nuclear axis when observed from that direction.

下列有關 σ 鍵與 π 鍵的敘述，何者錯誤？

(A) σ 鍵可由原子軌域沿著兩原子核間軸的方向重疊結合而成。

(B) π 鍵可由兩個 p 軌域平行重疊而成，在核間軸上的電子密度為零。

(C) σ 鍵存在於單鍵或多鍵中，而 π 鍵僅能存在於多鍵中。

(D) p 軌域間無法形成 σ 鍵。

(E) σ 鍵產生時，若沿著核間軸的方向觀察，電子雲對稱分布。

（南一版 110 下課本（選修化學 II）第一章 第 79 頁 練習 4）

Teacher: In this question we are to identify the characteristics of σ and π bonds. We can start by drawing the overlapping state of the σ and π bonds and their internuclear axis. First, how should the σ bond overlap?

Student: Overlap in a head-to-head fashion.

Teacher: What orbitals can form σ bonds?

Student: Both s and p orbitals can form σ bonds.

Teacher: Yes. If we observe along the internuclear axis, will we see a symmetrical distribution of electron clouds?

Student: Yes. By folding along the internuclear axis, which acts as the axis of symmetry, we can observe that the electron cloud is symmetrically distributed.

Teacher: Great, so how should π bonds overlap?

Student: They should overlap side-to-side.

Teacher: Yes. Is there an electron cloud distribution along the internuclear axis of a π bond?

Student: No, the electron density is zero along the internuclear axis of a π bond.

Teacher: Great. Which types of bond orders contain σ bonds then?

Student: Single bonds, double bonds, and triple bonds all contain σ bonds.

Teacher: How about π bonds? Which types of bond orders contain π bonds?

Student: Only double bonds and triple bonds contain π bonds.

Teacher: That's correct. So only statement (D) in this question is incorrect.

老師： 這一題是判斷 σ 鍵與 π 鍵的特徵，我們可以先畫出 σ 鍵與 π 鍵重疊的狀態以及他們的核間軸，首先 σ 鍵應該如何重疊呢？

學生： 以頭對頭的方式重疊。

老師： 可以形成 σ 鍵的軌域有哪些呢？

學生： s 和 p 軌域都可以。

老師： 沒錯，如果沿著核間軸的方向觀察的話，會看到電子雲對稱分佈嗎？

學生： 有，以核間軸為對稱軸對折可以發現電子雲是對稱分佈。

老師： 很棒，那麼 π 鍵應該如何重疊呢？

學生： 以側對側的方式重疊。

老師： 沒錯，那 π 鍵的核間軸有電子雲分佈嗎？

學生： 沒有，電子密度是 0。

老師： 很棒，那麼哪幾種鍵級中存在 σ 鍵呢？

學生： 單鍵、雙鍵和參鍵都存在 σ 鍵。

老師： 那麼哪幾種鍵級中存在 π 鍵呢？
學生： 只有雙鍵和參鍵存在 π 鍵。
老師： 沒錯，所以這題只有(D)選項的敘述是錯的。

例題二

說明：學生能透過混成軌域判斷分子的形狀。

Students can determine the shape of molecules through hybrid orbitals.

Which of the following molecules have all their atoms in the same plane?

(A) Ethene (B) Methane **(C) Boron trifluoride** (D) Ammonia **(E) Benzene**

下列哪些分子的原子都在同一平面上？

(A)乙烯 (B)甲烷 **(C)三氟化硼** (D)氨 **(E)苯**

（翰林版 110 下課本（選修化學 II）第二章 第 43 頁 習題 16）

Teacher: The purpose of this question is to use hybrid orbitals and lone electrons to determine the shapes of the molecules. First of all, what is the hybrid orbital of ethene?

Student: Ethene has sp^2 hybridized orbitals.

Teacher: That's correct. What is its shape then?

Student: Planar.

Teacher: Yes, ethene is planar, so all atoms are in the same plane. What about methane? What are the hybrid orbitals and molecular shape of methane?

Student: Methane has sp^3 hybrid orbitals and no lone pairs, so its shape is tetrahedral.

Teacher: Great. Now, what are the hybrid orbitals and molecular shape of boron trifluoride then?

Student: Boron trifluoride has sp^2 hybrid orbitals and no lone pairs, so its shape is a planar triangle.

Teacher: Great job! What are the hybrid orbitals and molecular shape of ammonia?

Student: Ammonia has sp^3 hybrid orbitals with one lone pair, so its shape is a triangular pyramid

Teacher: What about the hybrid orbitals and molecular shape of benzene?

Student: Each carbon atom in benzene is sp^2 hybrid orbitals, and it is a planar molecule.
Teacher: Good job! So which ones are planar molecules?
Student: Ethene, boron trifluoride, and benzene. So the correct answers are (A) (C) and (E).

老師： 這一題目的是利用混成軌域和孤電子對判斷分子的形狀，首先乙烯的混成軌域為何呢？
學生： 乙烯是 sp^2 混成軌域。
老師： 沒錯，所以是什麼形狀呢？
學生： 平面形。
老師： 對，乙烯是平面的，所以原子都在一個平面上。接著甲烷的混成軌域和分子形狀為何呢？
學生： 甲烷是 sp^3 混成軌域，沒有孤電子對，所以形狀是四面體。
老師： 很棒，那麼三氟化硼的混成軌域和分子形狀為何呢？
學生： 三氟化硼是 sp^2 混成軌域，沒有孤電子對，所以是平面三角形。
老師： 非常棒，氨的混成軌域和分子形狀為何呢？
學生： 氨是 sp^3 混成軌域，有一對孤電子對，所以形狀是三角錐。
老師： 最後，苯的混成軌域和分子形狀為何呢？
學生： 苯的每一個碳原子都是 sp^2 混成軌域，是一個平面分子。
老師： 很好！所以哪些是平面的分子呢？
學生： 乙烯、三氟化硼和苯。因此正確的選項是(A) (C) (E)。

2-4 分子間的作用力
Intermolecular Forces

■ 前言 Introduction

本小節教師帶領學生進一步認識化學鍵如何影響分子的結構與極性，並介紹偶極-偶極力、偶極-誘發偶極力、分散力、氫鍵等四種分子間的作用力，以及如何影響物質的狀態、熔點、沸點和溶解度等性質。

在進入本小節前，教師可先確認學生是否已熟悉原子結構、化學鍵等相關單字，進入教學後，可提供「定義關鍵術語」的句型，確保學生熟悉與分子間的作用力相關的術語。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
polar covalent bond	極性共價鍵	nonpolar covalent bond	非極性共價鍵
polarity	極性	electronegativity	電負度
bond dipole	鍵偶極	bond moment	鍵矩
dipole moment	偶極矩	dipole-dipole force	偶極-偶極力
induced dipole-dipole force	偶極-誘發偶極力	dispersion force	分散力
hydrogen bond	氫鍵	van der Waals force	凡得瓦力

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

❶ _____ be defined as _____.

例句：The magnitude of the bond dipole **is defined as** the product of the partial charge transferred between the two atoms and the distance between them.
鍵偶極的大小定義為兩原子移轉的部分電荷與原子間距離的乘積。

❷ When _____, resulting in_____.

例句：**When** the bond dipoles within a molecule cancel each other out**, resulting in** a zero net dipole moment, the molecule is nonpolar and is referred to as a nonpolar molecule.
當分子內各個鍵偶極互相抵消，分子偶極矩為零時，此分子不具極性，稱為非極性分子。

❸ _____depends on _____.

例句：The strength of dipole-dipole forces **depends on** the size of the molecular dipole moment. Generally, the larger the dipole moment, the stronger the forces between large molecules.
偶極-偶極力的強度取決於分子偶極矩的大小，通常偶極矩越大，大分子間的偶極-偶極力就越強。

❹ _____, as _____, _____.

例句：Nonpolar molecules still exert forces on each other, **as** the rapid movement of electrons can cause momentary uneven electron distribution, resulting in instantaneous dipoles and induced dipoles in neighboring molecules.
非極性分子之間仍有相互作用的力，這是因為電子高速運動所致，可能在瞬間造成電子分佈不均，產生瞬間偶極，再誘發相鄰分子偶極。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

After this lesson, students should be able to know:

學生能了解四種分子間作用力的基本性質及定義。

Students can understand the basic properties and definitions of the four types of intermolecular forces.

❧ 例題講解 ☙

例題一

說明：學生能判斷分子之間作用力的種類。

Students can identify the types of intermolecular forces between molecules.

Which of the following statements about the main intermolecular forces in each substance is correct?

(A) The main intermolecular force in BF_3 is dipole-dipole force.

(B) The main intermolecular force in Xe is dispersion force.

(C) The main intermolecular force in H_2 is hydrogen bonding.

(D) The main intermolecular force in C_2H_4 is covalent bonding.

(E) The main intermolecular force in HCl is ionic bonding.

下列有關各物質的分子間主要作用力的敘述，何者正確？

(A) BF_3 主要作用力為偶極-偶極作用力。

(B) Xe 主要作用力為分散力。

(C) H_2 主要作用力為氫鍵。

(D) C_2H_4 主要作用力為共價鍵。

(E) HCl 主要作用力為離子鍵。

（110 指考第 6 題）

Teacher: This question requires students to identify the types of intermolecular forces between different molecules. First, let's review the various types of intermolecular forces.

Student: There are dipole-dipole forces, induced dipole-dipole forces, dispersion forces, and hydrogen bonds.

Teacher: That's right. How are dipole-dipole forces formed?

Student: Dipole-dipole forces are generated when two polar molecules are close to each other.

Teacher: How are induced dipole-dipole forces formed?

Student: Dipole-induced dipole forces are formed when a polar molecule comes near a nonpolar molecule.

Teacher: How are dispersion forces formed?

Student: Dispersion forces occur because the constant motion of electrons causes uneven distribution of electrons in nonpolar molecules, creating instantaneous dipoles in two nonpolar molecules.

Teacher: Great. How are hydrogen bonds formed?

Student: Hydrogen bonds are the attraction between the lone electron pairs of H and F, N, or O.

Teacher: Excellent. Now we can identify the intermolecular forces of the different molecules in the answer choices. What is the intermolecular force between BF_3 molecules?

Student: BF_3 is a nonpolar molecule, so the intermolecular force between the molecules is dispersion force.

Teacher: What is the intermolecular force between Xe molecules?

Student: Xe is a nonpolar molecule, so the intermolecular force between the molecules is dispersion force.

Teacher: What is the intermolecular force between H_2 molecules?

Student: H_2 is a nonpolar molecule, so the intermolecular force between the molecules is dispersion force.

Teacher: What is the intermolecular force between C_2H_4 molecules?

Student: C_2H_4 is a nonpolar molecule, so the intermolecular force between the molecules is dispersion force.

Teacher: What is the intermolecular force between HCl molecules?

Student: HCl is a polar molecule, so the intermolecular force between the molecules is dipole-dipole force.

Teacher: Excellent. So only option (B) is correct.

老師： 這題要求學生辨識不同分子間的分子間作用力類型。在此之前，我們先來複習一下各種分子間作用力的類型。

學生： 有偶極-偶極力、偶極-誘發偶極力、分散力和氫鍵。

老師： 沒錯，那偶極-偶極力如何形成呢？

學生： 偶極-偶極力是兩個極性分子靠近產生的。

老師： 偶極-誘發偶極力如何形成呢？

學生： 偶極-誘發偶極力是極性分子靠近非極性分子形成的。

老師： 分散力如何形成呢？

學生： 分散力是因為電子不停運動，使非極性分子的電子產生不均勻分布，兩個非極性分子產生瞬間偶極。

老師： 很棒，那氫鍵是如何形成呢？

學生： H 和 F、N、O 的孤電子對之間產生的吸引力。

老師： 非常棒，接著我們就可以判斷選項中各個分子的作用力了。BF_3 分子間的作用力是什麼呢？

學生： BF_3 是非極性分子，所以分子間的作用力是分散力。

老師： Xe 分子間的作用力是什麼呢？

學生： Xe 是非極性分子，所以分子間的作用力是分散力。

老師： H_2 分子間的作用力是什麼呢？

學生： H_2 是非極性分子，所以 分子間的作用力是分散力。

老師： C_2H_4 分子間的作用力是什麼呢？

學生： C_2H_4 是非極性分子，所以分子間的作用力是分散力。

老師： HCl 分子間的作用力是什麼呢？

學生： HCl 是極性分子，所以分子間的作用力是偶極-偶極力。

老師： 非常棒，所以只有(B)選項是正確的。

例題二

說明：學生能認識化學鍵及分子極性的形成原因和關係。

Students can understand the causes and relationships of chemical bond formation and molecular polarity.

Which of the following statements about chemical bonds and molecular polarity is incorrect?

(A) Ionic bonds are mainly caused by electrostatic forces between anions and cations.

(B) The dipole moment of a covalent bond is caused by the uneven distribution of the bonding electron pair between two bonded atoms.

(C) Linear molecules cannot have polarity.

(D) In a polar covalent bond, the electron pair is typically closer to the more electronegative atom.

(E) Nonpolar molecules can have polar covalent bonds.

下列有關化學鍵及分子極性的敘述，何者錯誤？

(A) 離子鍵主要是由陰離子與陽離子間的靜電引力所造成。

(B) 共價鍵的偶極矩主要是因鍵結電子對在兩鍵結原子間分布不均所致。

(C) 直線形的分子不可能具有極性。

(D) 極性共價鍵中的電子對，通常靠近電負度較大的原子。

(E) 非極性分子可能具有極性共價鍵。

（南一版 110 下課本（選修化學 II）第一章 第 114 頁 單選題第 8 題）

Teacher: This question mainly asks about the causes of different chemical bond formation and their relationship with molecular polarity. First, how is an ionic bond formed?

Student: An ionic bond is formed by the Coulombic electrostatic force between an anion and a cation.

Teacher: Correct, so option (A) is correct. Next, how is a dipole moment formed?

Student: The dipole moment is formed because the electronegativity of different atoms in the molecule is different, resulting in an uneven distribution of electrons.

Teacher: Great, so do electrons tend to be closer to atoms with higher or lower electronegativity?

Student: Atoms with higher electronegativity.

Teacher: Correct, then can nonpolar molecules have polar covalent bonds?

Student: Yes, because some molecules have polar covalent bonds that are canceled out because of the molecular shape.

Teacher: Can you give an example?

Student: For example, CCl_4.

Teacher: Correct, C-Cl bond is a polar covalent bond, Because the structure of CCl_4 is tetrahedral, it is a nonpolar molecule. Although each C-Cl bond is polar, the four C-Cl bonds' dipole vectors cancel each other out due to the tetrahedral symmetry of the CCl_4 molecule, resulting in no net polarity for the entire molecule.
making CCl_4 a nonpolar molecule. Can linear molecules have polarity?

Student: It is possible, such as HCN, where the electronegativity of the atoms on either side of C is different, resulting in polarity.

Teacher: Very good, so options (A) (B), (D), and (E) are also correct. Only option (C) is incorrect.

老師： 這一題主要在問不同化學鍵的形成原因，以及分子極性的關係。首先，離子鍵是如何形成呢？

學生： 離子鍵是陰離子和陽離子藉由庫倫靜電力形成的化學鍵。

老師： 沒錯，所以(A)選項是對的。那麼偶極矩是如何形成的呢？

學生： 形成偶極矩的原因是因為分子中不同原子的電負度不同，對電子的吸引力不同，導致電子密度不均造成的。

老師： 很棒，那麼電子會靠近電負度大還是小的原子呢？

學生： 電負度大的原子。

老師： 沒錯，那麼非極性分子會具有極性共價鍵嗎？

學生： 會，因為有些分子雖然具有極性共價鍵，但是因為分子形狀而使極性鍵互相抵消了。

老師： 可以舉一個例子嗎？

學生： 例如 CCl_4。

老師： 沒錯，C-Cl 鍵是極性共價鍵，但是因為 CCl_4 的結構是四面體，四氯化碳（CCl_4）是非極性分子，雖然每個 C-Cl 鍵都有極性，但由於四氯化碳分子呈四面體對稱結構，四個 C-Cl 鍵的極性向量相互抵消，最終使整個分子沒有總的極性。CCl_4 使是一個非極性分子(極性鍵可以互相抵銷的說法可能不清楚。實際上，四氯化碳為非極性分子是分子內所有的極性鍵的向量結果為零)。那麼直線形的分子可能具有極性嗎？

學生： 可能，像是 HCN，C 兩邊的原子電負度不一樣，所以會有極性。

老師： 非常棒，所以(A)(B)(D)(E)選項也是對的，只有(C)選項是錯的。

★主題三 化學反應速率★
Chemical Reaction Rate

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■ 前言 Introduction

本章首先介紹反應速率的定義、反應速率與反應物間的關係以及反應速率的表示方式，接著從碰撞學說的角度了解碰撞頻率的高低、方位及能量大小均是影響反應進行快慢的因素，最後再以碰撞學說的角度，深入探討反應物的本質、濃度、接觸面積、溫度及催化劑等影響反應速率的原因。

本章中，學生將學習多樣的轉折語，例如表達順序性及因果關係的慣用語。

3-1 反應速率定律
Reaction Rate Law

■ 前言 Introduction

在此小節，教師可先引導出學生國中階段學過的反應速率定義，介紹反應速率的測定，接著帶學生了解速率定律與速率常數，零級一級反應與半生期，再透過介紹放射性碳-14定年法讓學生了解半生期的應用。

學生將學習描述實驗過程及實驗發現相關的句型與轉折語，以進行學習活動。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
reaction rate	反應速率	colorimeter	比色計
femtosecond	飛秒（10^{-15} 秒）	rate law	速率定律
average consumption rate of reactants	反應物平均消耗速率	rate constant	速率常數
average rate of product formation	生成物平均生成速率	zero order reaction	零級反應
instantaneous rate	瞬時速率	half life	半生期
conductivity	導電度	first order reaction	一級反應
conductivity meter	導電度計	radiocarbon-14 dating	放射性碳-14定年法
precipitation	沉澱	reaction order	反應級數

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

❶ As time progresses, _____.

例句：During a chemical reaction, **as time progresses**, the amount of reactants decreases, but the amount of products increases.

在化學反應的過程中，隨著時間增加，反應物的量遞減，但生成物的量遞增。

❷ That is to say, _____. = In other words, _____.

例句：During the same reaction time, the ratio of reaction rates between different species is equal to the ratio of their equilibrium coefficients in the reaction equation. **That is to say**, within the same reaction time, the reaction rate ratio between different species is the balance coefficient ratio between species in the chemical equation.

= During the same reaction time, the ratio of reaction rates between different species is equal to the ratio of their equilibrium coefficients in the reaction equation. **In other words**, within the same reaction time, the reaction rate ratio between different species is the balance coefficient ratio between species in the chemical equation.

在相同的反應時間內，不同物種之間的反應速率比與反應式中對應物種的平衡係數比相等。也就是說，在相同的反應時間內，各物種間的反應速率比為反應式中各物種間的平衡係數比。

❸ Therefore, we can learn that _____.

例句：**Therefore, we can learn that** this reaction is a first-order reaction for H_2, and a second-order reaction for NO, and the total reaction coefficient is 3, that is, a third-order reaction.

由此可知，此反應對 H_2 而言是一級反應，對 NO 是二級反應，總反應係數是 3，即三級反應。

❹ _____have nothing to do with _____.

例句：In the process of first-order reaction, the half-life is a certain value, which **has nothing to do with** the concentration of reactants.

一級反應的過程中，半生期為一定值，與反應物濃度無關。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能了解反應速率的意義及速率定律的計算。

Students can understand the meaning of reaction rate and the calculation of rate law.

❧ 例題講解 ☙

例題一

說明：學生能依據表格寫出速率定率式並推導出速率常數。

Students can write the rate law formula and deduce the rate constant based on the table.

experiment number	[NO]（M）	[Cl_2]（M）	initial rate（M s^{-1}）
1	0.15	0.20	2.25×10^{-2}
2	0.30	0.20	9.00×10^{-2}
3	0.30	0.10	4.50×10^{-2}

A student used the initial rate method to detect the reaction rate of the following reactions:

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

The experimental data is shown in the table above.

Try to answer the following questions:

(1) Write down the rate law for this reaction. $\mathbf{r = k\,[NO]^2\,[Cl_2]^1}$

(2) Calculate the value of k and list the units. $\boldsymbol{k = 5.0}$（$\mathbf{M^{-2}s^{-1}}$）

實驗編號	[NO]（M）	[Cl_2]（M）	初速率（M s^{-1}）
1	0.15	0.20	2.25×10^{-2}
2	0.30	0.20	9.00×10^{-2}
3	0.30	0.10	4.50×10^{-2}

某生利用初速率法檢測下列反應的反應速率：$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$，
其實驗數據如上表。試回答下列問題：

(1) 寫出此反應的速率定律。**$r = k\,[NO]^2\,[Cl_2]^1$**

(2) 求出 *k* 值的大小並列出單位。***k*＝5.0（$M^{-2}s^{-1}$）**

（南一版 110 下課本（選修化學 II）_第 03 章 第 133 頁 例題 3-3）

Teacher: In this question, we are going to explore the relationship between the concentration of the participating reactants and the rate, so we can infer the correlation between the concentration of each reactant and the rate. Now, what formula can we list first based on what we have learned in class?

Student: $r = k\,[NO]^x\,[Cl_2]^y$.

Teacher: That's right. We can compare and bring in the statistics of different experiment in the table to find out x and y. So, how do we find x and y?

Student: In Experiments 1 and 2, [Cl_2] is the same, but [NO] in Experiment 2 is twice that of experiment 1, and the rate becomes four times. So it can be inferred that x=2. On the other hand, in Experiment 2 and 3, [NO] are the same, but [Cl_2] in Experiment 2 is twice that of experiment 3, and the rate becomes 2 times, so it can be inferred that y=1, so the rate law formula can be $r = k\,[NO]^2\,[Cl_2]^1$.

Teacher: Very well. Now let's find out the relationship between the reactant concentration and the reaction rate. To formulate the equation, we need a rate constant k. How do we find it?

Student: Bring the rate law formula into one of the experiments to obtain it. If the data in Experiment 1 is brought into the formula $2.25 \times 10^{-2} = k \times (0.15)^2 \times (0.20)$, we can get k=5 ($M^{-2}s^{-1}$).

老師：此題在探討參與的反應物濃度與速率的關係，因此我們可以由此推斷各項反應物濃度與速率的相關性，所以我們由課堂中所學，可以先列出什麼式子？

學生：$r = k\,[NO]^x\,[Cl_2]^y$。

老師：沒錯，我們可以比較表中不同實驗的數據、帶入找出 x 與 y，所以 x 與 y 該如何求出呢？

學生：找實驗編號 1、2，$[Cl_2]$相同，實驗 2[NO]為實驗 1 的兩倍，速率變四倍，因此可推斷 x=2。而實驗編號 2、3，[NO]相同，實驗 2$[Cl_2]$為實驗 3 的兩倍，速率變 2 倍，因此可推斷 y=1，因此可得速率定律式為 $r = k\,[NO]^2\,[Cl_2]^1$。

老師：很好，那現在我們找出反應物濃度與反應速率的關係，因此為了列出等式需要一個速率常數 k，那我們該如何求出？

學生：將速率定律式帶入其中一個實驗求得，若帶入實驗 1 可列出式子 $2.25 \times 10^{-2} = k \times (0.15)^2 \times (0.20)$，及可得到 k=5（$\mathbf{M^{-2}s^{-1}}$）。

例題二

說明：學生能學會半生期的應用。

Students can learn the application of the half-life.

The decomposition reaction of a certain substance A is a first-order reaction, and its half-life is 10 minutes. Which of the following statement(s) is/are correct?

(A) When the reaction reaches the 35th minute, the concentration of A is half of that at the 25th minute.

(B) At the 20th minute of reaction, the concentration of A is 1/4 of the initial concentration.

(C) When the concentration of A is doubled, its half-life increases to 20 minutes.

(D) When the reaction reaches the 20th minute, the reaction rate is 1/8 of the initial rate.

(E) When the concentration of A is halved, the half-life is shortened to 5 minutes.

某物質 A 之分解反應為一級反應，其半生期為 10 分鐘，下列敘述哪些正確？

(A) 反應至第 35 分鐘時，A 的濃度為反應至第 25 分鐘時的一半。

(B) 反應至第 20 分鐘時，A 的濃度為初濃度的 1/4。

(C) 將 A 之濃度加倍時，其半生期增長為 20 分鐘。

(D) 反應至第 20 分鐘時，反應速率為初速率之 1/8。

(E) 將 A 之濃度減半時，半生期減短為 5 分鐘。

（來源：龍騰版 110 下課本（選修化學 II）第三章 第 126 頁 練習 3-5）

Teacher: Based on what we learned, for a first-order reaction, does the half-life change with changes in concentration?

Student: No, the half-life of a first-order reaction will be fixed. Therefore, (C) and (E) are incorrect.

Teacher: That's right. According to the data given, if the reaction reaches the 20th minute, the half-life of substance A is 10 minutes. How will the concentration of A change?

Student: The concentration of A should be reduced to 1/4 of its original amount because it has undergone two decay periods.

Teacher: How will the initial rate of the reaction rate change?

Student: The same 1/4 of the initial rate. Because this reaction is a first-order reaction, the concentration of reactants will be proportional to the reaction rate. Therefore (B) is correct but (D) is incorrect.

Teacher: Very well. Is (A) true? Is the concentration of A half of that at the 25th minute when the reaction reaches the 35th minute?

Student: That's correct, because another half-life has passed from the 25th minute to the 35th minute. So the concentration will become half of that at the 25th minute.

Teacher: That's right, so the answer should be (A) and (B).

老師： 在課堂中我們學過若是一級反應，則半生期會因為濃度變化而改變嗎？

學生： 不會，一級反應的話半生期會固定。因此可知(C)(E)敘述錯誤。

老師： 沒錯。若反應至第 20 分鐘，根據題目所說此物質 A 半生期為 10 分鐘，則 A 濃度應如何變化？

學生： A 濃度應變為原來的 1/4，因為經過了兩次的衰變。

老師： 那反應速率的初速率會如何變化？

學生： 一樣是原來的 1/4 倍，因為此反應為一級反應，反應物濃度會與反應速率成正比。因此(B)正確(D)錯誤。

老師： 很好，那(A)的敘述反應至第 35 分鐘時，A 的濃度為反應至第 25 分鐘時的一半是否正確？

學生： 正確，因為第 25 分鐘至第 35 分鐘又經過了一次半生期，因此濃度會在變成第 25 分鐘的一半。

老師： 沒錯，因此答案要選(A)(B)。

3-2 碰撞學說
Collision Theory

■ 前言 Introduction

此小節教師以微觀角度讓學生了解化學反應時反應物之間的粒子碰撞，及再導入碰撞學說基本理論，接著講解反應能量圖、活化能與活化複合體來引導學生了解化學反應的速率決定步驟。

此小節的句型著重在讓學生能夠從理論中觀察並進行描述。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
collision theory	碰撞學說	transition state	過渡狀態
effective collision	有效碰撞	activation energy	活化能
threshold energy	低限能	reaction mechanism	反應機構
reaction energy diagram	反應能量圖	rate-determining step	速率決定步驟
activated complex	活化複合體	mid product/intermediate product	中間產物

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

❶ First, _____, and second _____.

例句：There are two conditions for an effective collision. **First,** the particles have must sufficient energy**, and second**, they must have an appropriate collision orientation.
有效碰撞的條件有兩項，首先，粒子具有足夠的能量，再來，要有適當的碰撞位向。

❷ _____ can be seen as _____.

例句：Activation energy **can be seen as** an energy barrier that a chemical reaction needs to overcome.
活化能如同一個化學反應需要克服的能量障壁。

❸ It can only be made possible (_____) if _____.

例句：**It can only be made possible** for reactions to happen **if** there is enough energy to make the kinetic energy of the reactant exceed the threshold energy.
在化學反應過程中，須具有足夠的能量，使反應物的動能超越低限能，反應才有可能發生。

❹ neither_____ nor _____.

例句：Among them, N_2O_2 is **neither** a reactant **nor** a final product, and is called an intermediate.
其中 N_2O_2 既不是反應物，也不是最終生成物，稱為中間產物。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應學會以下觀念：

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

學生能學會判斷並理解反應能量圖。

Students can learn to interpret and understand reaction energy diagrams.

❧ 例題講解 ☙

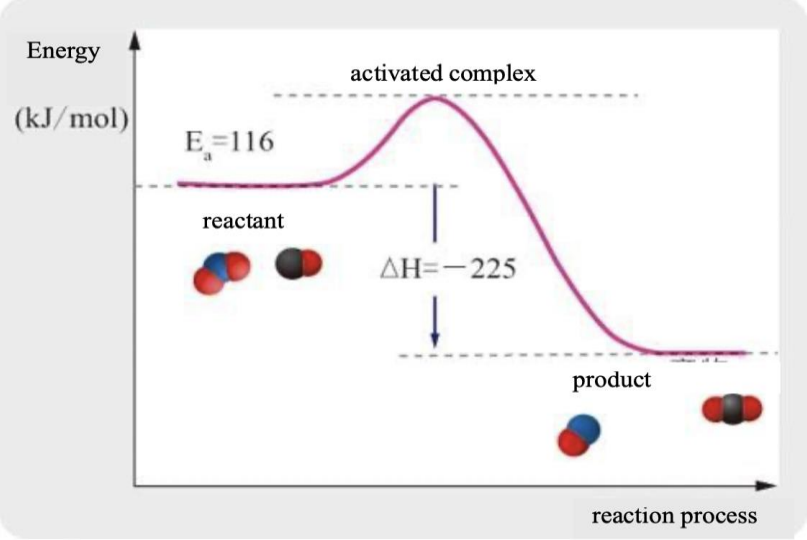
例題一

說明：學生能夠學會看反應能量圖並學會計算出逆反應的活化能。

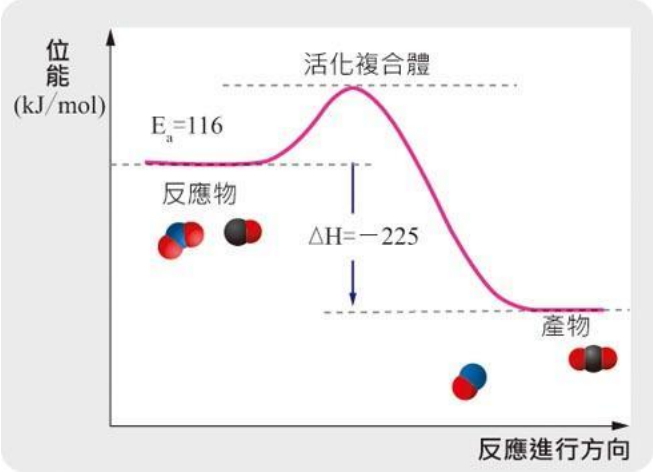
Students can learn to interpret reaction energy diagrams and calculate the activation energy of the reverse reaction.

The figure below shows the change of potential energy during the process of a chemical reaction: $CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$. Try to calculate the activation energy of the reverse reaction. Under the same circumstances, which is more likely to occur, the forward or the reverse reaction?

Ea'=341 kJ/mol. The forward reaction.



已知有一化學反應進行過程中，其位能的變化情形如下圖所示，$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$ ，試計算其逆反應的活化能為多少？相同的情況下，正、逆反應何者較易發生？**E_a'＝341 kJ/mol。正反應。**



（南一版 110 下課本（選修化學 II）第三章 例題 3-1）

Teacher:	First of all, we can see from the figure that the positive reaction activation energy of the reactant is 116 kJ/mol. Can we tell the reaction is an endothermic reaction or an exothermic reaction?
Student:	It’s an exothermic reaction.
Teacher:	That's right. How much heat is released in this reaction?
Student:	－225kJ/mol
Teacher:	That's right. Then, how do we determine the activation energy of the reverse reaction with the data given in the question?
Student:	The heat of reaction of this reaction can be obtained by subtracting the activation energy of the reverse reaction from the activation energy of the forward reaction. By using the equation 116 kJ/mol -Ea'= －225 kJ/mol, the activation energy of the reverse reaction can be obtained as 341kJ/mol.
Teacher:	That's right. Under the same circumstances, which is easier to carry out, the forward reaction or the reverse reaction?
Student:	The forward reaction. Because the activation energy of the reverse reaction is larger, it is not easy to carry out. On the other hand, the activation energy required for the forward reaction is smaller, so it is easier to carry out.

老師： 首先我們從圖表來看能看出反應物的正反應活化能為 116kJ/mol，由圖來看我們能知道此反應是一個吸熱反應還是放熱反應？

學生： 放熱反應。

老師： 沒錯，那此反應放出了多少熱量？

學生： −225kJ/mol 如何利用已知來求得逆反應活化能

老師： 沒錯，那由題目要求的逆反應活化能該如何利用已知來求得？

學生： 利用正反應的活化能減掉逆反應活化能，即可得到此反應的反應熱，因此可列出式子 116 kJ/mol - Ea' = −225kJ/mol ，可得逆反應活化能為 341kJ/mol

老師： 沒錯，那在相同情況下，正、逆反應誰會較容易進行？

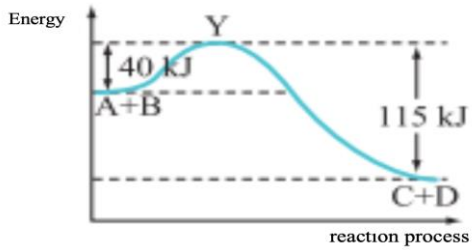
學生： 正反應，因為逆反應活化能較大，因此較不容易進行，而正反應需要的活化能較小，因此較容易進行。

例題二

說明：學生能利用圖表計算出反應熱，並了解反應能量圖中反應物、活化複合體及生成物的位置。

Students can use graphs to calculate the heat of reaction, and learn to understand the positions of reactants, activated complexes, and products in the reaction energy diagram.

The attached figure shows the reaction energy diagram of the reaction process of A + B → C + D. Which of the following statement(s) is/are correct?



(A) In the figure, A, Y, and D represent reactants, activated complexes, and products respectively.

(B) The energy of the activated complex is 115 kJ higher than that of the product.

(C) This reaction is endothermic, $\Delta H > 0$.

(D) The activation energy for the forward reaction is 40 kJ.

(E) The reverse reaction of the reaction is easier to carry out than the forward reaction.

附圖為 A + B → C + D 的反應過程之反應能量圖，下列敘述哪些正確？

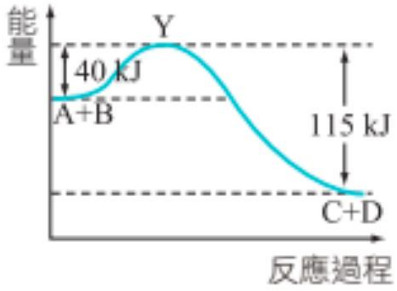
(A) 圖中 A、Y、D 各表示反應物、活化複合體、生成物。

(B) 活化複合體能量比生成物能量高 115 kJ。

(C) 此反應為吸熱反應, ΔH > 0。

(D) 正反應活化能為 40 kJ。

(E) 反應的逆反應較正反應容易進行。



（龍騰版 110 下課本（選修化學 II）第三章 第 132 頁 例題 3-6）

Teacher: For (A), we need to determine what A, Y, and D are. Is the statement correct?

Student: Yes. The reaction process begins with the reactants, then proceeds through the transition state, reaches the activated complex Y, and finally ends with the products. So option (A) is correct.

Teacher: How about (B)? Is the energy of the activated complex 115 kJ higher than that of the product?

Student: That's right. The energy difference between the energy corresponding to Y and the energy corresponding to the product C+D is 115kJ. So it is correct.

Teacher: It can be seen from the figure that the energy of the reactant is higher at the beginning, while the energy of the product is lower. Is the reaction in (C) endothermic or exothermic then?

Student: It’s an exothermic reaction.

Teacher: The activation energy of the forward reaction can be calculated from the energy difference between the reactant and the activated complex. So, is option (D) correct?

Student: The energy difference from A+B to Y is 40kJ. So option (D) is correct.

Teacher: Option (E) asks whether the forward reaction or the reverse reaction is easier to carry out. How do we tell?

Student: By looking at the respective activation energies of the forward and reverse reactions, we can tell that the forward reaction activation energy of this reaction is lower. So the forward reaction is easier to proceed.

老師： (A)選項要判斷 A、Y、D 是什麼，請問(A)選項的描述是否正確？

學生： 對，首先反應過程一開始應為反應物，再來經過反應到過渡狀態，到達 Y 的活化複合體，最後到反應結束為生成物。所以(A)選項正確。

老師： 那(B)選項的描述說活化複合體能量比生成物能量高 115 kJ 是否正確？

學生： 沒錯，由 Y 對應的能量至 C+D 生成物對應的能量差，為 115kJ。所以正確。

老師： (C)選項由圖可知，反應物一開始的能量較高，而生成物能量較低，因此此反應是吸熱反應還是放熱反應？

學生： 放熱反應。

老師： 正反應活化能可由反應物到活化複合體之間的能量差計算求出，因此(D)選項是否正確？

學生： A+B 到 Y 的能量差為 40kJ 因此(D)選項正確。

老師： 此反應要判斷正反應較容易進行,還是逆反應. 可由正逆反應的什麼來判斷出來呢？

學生： 由正逆反應各自的活化能來判斷，此反應的正反應活化能較低，因此正反應較容易進行。

3-3 影響反應速率的因素
Factors in the Reaction Rate

■ 前言 Introduction

此小節中教師複習學生在國中所學之影響反應速率的因素有反應物的本質、濃度、接觸面積、溫度及催化劑等，並藉由碰撞學說、分子動能、活化能與活化複合體，更深入探討各個因素增加反應速率的原因。

語言方面，教學前教師可以先確定學生是否熟悉催化劑、反應速率等單字，教學時，教師可以提供學生情境或是以生活中的例子來表達類型的訓練。要注意學生是否理解各項之間的關係，比如說連接詞或是轉折語的使用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
homogeneous reaction	均相反應	heterogeneous reaction	非均相反應
Haber process	哈柏法	catalyst	催化劑
enzyme	酵素	specificity	專一性
threshold energy	低限能	kinetic energy of molecule	分子動能
substrate	受質		

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

❶ There are many factors _____, including _____.

例句：**There are many factors** that affect the rate of reaction, **including** the nature of the reactants, concentrations, pressure, surface area, temperature, and catalysts.
影響反應速率快慢的因素很多，包含反應物的本質、濃度、壓力、接觸面積、溫度與催化劑等。

❷ _____, while _____.

例句：Reactions with higher activation energy tend to have slower reaction rates**, while** reactions with lower activation energy tend to have faster reaction rates.
活化能較大的反應，其反應速率較慢，而活化能較小者，其反應速率則較快。

❸ When _____ is _____, the reaction rate is usually faster.

例句：**When** the concentration of reactants **is** higher, or when the contact area between reactants is larger**, the reaction rate is usually faster.**
反應物濃度愈高，或反應物間的接觸面積愈大時，通常反應速率則較快。

❹ The –er …, the –er ….

例句:**The higher** the contact area between reactants, **the faster** the reaction rate usually becomes.
反應物之間的壓力越大，反應速率通常越快。

❺ _____ be divided into _____ and _____.

例句：The catalytic reaction can **be divided into** homogeneous catalytic reactions, where both reactants and catalysts are in the same phase, **and** heterogeneous catalytic reactions, where they are in different phases.
催化反應可分為反應物和催化劑均在同相中進行的均相催化反應，及兩者在不同相間進行的非均相催化反應。

■ 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:

學生能了解影響反應速率的因素及了解動態分佈曲線圖。

Students can understand the factors in the reaction rate and interpret dynamic distribution curves.

❧ 例題講解 ☙

例題一

說明：學生能依據不同溫度下分子動能的分布曲，線解釋溫度對反應速率的影響。

Students can explain the effect of temperature on reaction rates based on the distribution curves of molecular kinetic energy at different temperatures.

The attached figure shows the dynamic distribution curves of the same reaction at different temperatures. Which of the following statement(s) is /are correct?

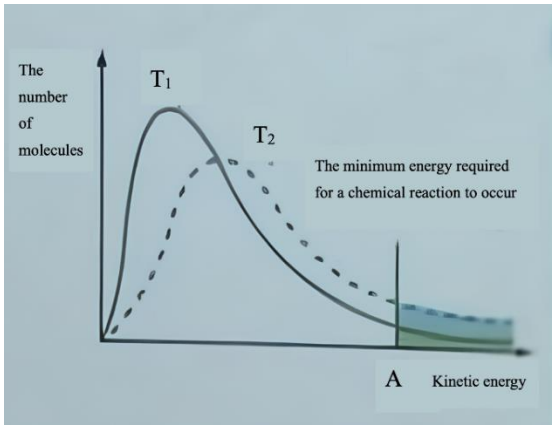
(A) Temperature: $T_1 > T_2$.

(B) The number of molecules with energy above the threshold energy: $T_2 > T_1$.

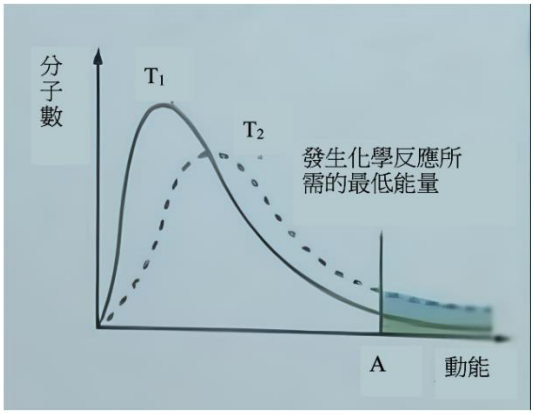
(C) When the temperature increases, point A moves to the left, and thus the reaction rate increases.

(D) Average molecular kinetic energy: $T_2 > T_1$.

(E) Effective collision frequency: $T_1 > T_2$.



附圖為同一反應在不同溫度時的動態分佈曲線，下列敘述哪些正確？



(A)　溫度：$T_1>T_2$。

(B)　具有低限能以上能量的分子數：$T_2>T_1$。

(C)　溫度升高時，A 點向左移，故反應速率增大。

(D)　分子平均動能：$T_2>T_1$。

(E)　有效碰撞頻率：$T_1>T_2$。

（龍騰版 110 下課本（選修化學 II）第三章　第 138 頁　練習 3-7）

Teacher: This question is asking how temperature affects reaction rates. Which curve in the graph has a higher temperature?

Student: T_2 has a higher temperature, because as the temperature increases, the average kinetic energy of the particles increases, causing the curve to become lower and flatter.

Teacher: Great. Then how do we determine the number of molecules with energies above the threshold energy?

Student: If we look at the area to the right of point A, there are many molecules with T_2 energy exceeding the threshold energy.

Teacher: What about the effective collision frequency?

Student: The effective collision frequency is also higher at T_2.

Teacher: Great. Will the minimum energy required for the chemical reaction change if the temperature is increased?

Student: It won't change. Temperature only affects the kinetic energy of molecules.

Teacher: So which options are correct then?

Student: Option (B) and (D).

Teacher: That's right! So, only option (D) is incorrect.

老師： 這一題在問溫度如何影響反應速率，首先從曲線判斷哪個溫度高呢？
學生： T_2 溫度高，因為溫度升高，粒子的平均動能增加，曲線變得較為低平。
老師： 很棒，那麼具有低限能以上能量的分子數要怎麼看呢？
學生： 看 A 點右邊的面積，所以是 T_2 能量超過低限能的因為溫度升高，粒子的平均動能增加，曲線變得較為低平分子數目多。
老師： 那麼有效碰撞頻率呢？
學生： 也是 T_2 多。
老師： 非常棒，如果把溫度升高，化學反應所需的最低能量會改變嗎？
學生： 不會，溫度改變只會改變分子的動能。
老師： 所以哪些選項是正確的呢？
學生： (B)和(D)選項。
老師： 沒錯，所以這題只有(D)選項的敘述是錯的。

例題二

說明：學生能了解催化劑能改變反應速率的原因。

Students can understand the reason(s) why catalysts can change the reaction rate.

Which of the following statement(s) about catalysts is/are correct?

(A) Adding a catalyst can increase the yield of the product.

(B) Catalysts can change the distribution of molecular kinetic energy, making thus speeding up the reaction faster.

(C) Catalysts can catalyze both the forward and reverse reactions at the same time, so they cannot change the reaction rate.

(D) Adding a catalyst can lower the activation energy required for the reaction, thus increasing the reaction rate.

(E) Catalysts are not consumed, so they do not participate in the reaction.

下列關於催化劑的敘述，何者正確？

(A) 加入催化劑，可提升產物的產率。

(B) 催化劑能改變分子的動能分布，使反應加速。

(C) 催化劑可同時催化正、逆反應，所以無法改變反應速率。

(D) 加入催化劑，可使反應所需的活化能降低，故反應速率加快。

(E) 催化劑不會被消耗，故沒有參與反應。

（翰林版 110 下課本（選修化學 II）第三章 第 51 頁 習題 18）

Teacher: What is the purpose of adding a catalyst in a chemical reaction?
Student: To increase the reaction rate.
Teacher: Correct. Why can a catalyst increase the reaction rate?
Student: During the reaction, the catalyst will form an activation complex with a lower potential energy with the reactant, reducing the activation energy required for the reaction, increasing the effective collision frequency, and thus increasing the reaction rate.
Teacher: Great. Now we know that option (D) is correct. Let's see why the other options are wrong. First of all, can a catalyst increase the yield?
Student: No, the catalyst can only increase the reaction rate but the yield will not change.
Teacher: Correct. Can catalysts change the distribution of molecular kinetic energy?
Student: No, they can't.
Teacher: Among the factors in the reaction rate that we learned before, which one can change the kinetic energy distribution of molecules?
Student: Temperature.
Teacher: Great. Does the catalyst participate in the reaction?
Student: Yes, it will form an activated complex with the reactants.
Teacher: You all did a great job.

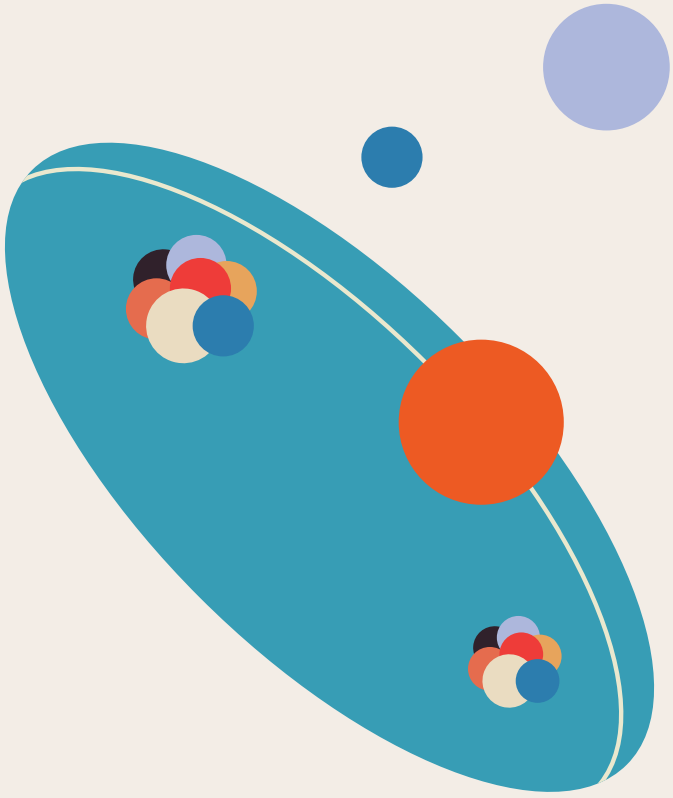
老師： 請問在化學反應中添加催化劑的目的是什麼呢？
學生： 增加反應速率。
老師： 沒錯，催化劑能增加反應速率的原因是什麼呢？
學生： 催化劑在反應中會與反應物形成位能較低的活化複合體，降低反應所需的活化能，使有效碰撞頻率增加，反應速率因此變快。
老師： 非常棒，這樣就可以知道(D)選項是對的，那我們來看其他選項錯在哪，首先催化劑可以提高產率嗎？
學生： 不行，催化劑只能提高反應速率，產率不會改變。
老師： 沒錯，那催化劑能改變分子的動能分佈嗎？
學生： 不行。
老師： 我們之前學過的影響反應速率的因素中，哪種因素可以改變分子的動能分佈呢？
學生： 溫度可以改變分子的動能分佈。
老師： 很棒，那麼催化劑有參與反應嗎？
學生： 有，它會跟反應物形成活化複合體。
老師： 你們都回答的很棒。

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

- 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：方宣幃、邱韋慈、劉俊億、徐毓瑩
- 學科諮詢：鄭碧雲
- 語言諮詢：儲湘君、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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