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(I)〕

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 物質鑑定與化學反應 ★
Substance Identification and Chemical Reactions

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■ 前言 Introduction

本章首先介紹各種物理和化學的鑑定方法，更深入介紹其鑑定原理；接著從高一已學過的化學反應式平衡延伸至利用氧化數來平衡化學反應式，並判斷限量試劑，更進一步計算產率；最後介紹反應熱的定義種類及熱化學反應式的寫法，以及利用赫斯定律計算未知的反應熱。

在學生參與課堂的過程中，以高一時學過的專有詞彙為基礎，學習更多更具體的詞彙。同時，將以單個句型累積成情境化的敘述，建議老師在課程中多提供學生清楚表達的機會，同時注意課室(或科學)英語的使用，以利師生間的提問與發表，並了解章節重點可應用的情境。

1-1 物質的特性與鑑定
Characterization and Identification of Substances

■ 前言 Introduction

本節藉由不同物質因鍵結、排列或結構不同，而具有不同的物理和化學性質，故可利用物理方法和化學方法來純化性質不同的物質，並深入介紹不同鑑定方法的原理。

語言部分，教師提供鑑定相關的單字用法，並以句型讓學生表達關聯性與使用時機，教師可以在學生完成單句後給予回饋，再讓學生能使用轉折語進行建構較長的情境。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
physical identification	物理鑑定	thin layer chromatography (TLC)	薄層色層分析
chemical identification	化學鑑定	stationary phase	固定相
solubility	溶解度	developing solvent	展開液
chromatography	色層分析	boiling point	沸點
melting point	熔點	capillary tube	毛細管
acid and alkali	酸鹼性	precipitate	沈澱
cation	陽離子	anion	陰離子

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

❶ _____ be related to of _____.
= _____ be associated with _____.

例句：The solubility in water **is related to** its chemical properties.
= The solubility in water **is associated with** its chemical properties.
物質於水中的溶解度與其化學性質有關係。

❷ ____ be subjected to _____.

例句：Under the condition of the fixed elution and filter paper, the same pure substance **is subjected to** the same force of developing solution and filter paper, so the ratio of the moving distance of pure substance and elusion will be the same.
在展開液和濾紙皆固定的條件下，同一純物質受到展開液與濾紙的作用力相同，因此純物質移動的距離相對於展開液移動的距離的比值也會相同。

❸ _____ be used to _____.

例句：Thin layer chromatography can **be used to** identify the painkillers sold in the market, such as acetaminophen, ibuprofen, or aspirin, and determine whether they contain caffeine.
薄層色層分析可用來鑑定市售止痛藥的止痛劑成分中是否含有乙醯胺酚、布洛芬或阿司匹靈，以及是否含有咖啡因。

❹ In addition, ____.

例句：**In addition**, we can also add a small amount of ammonia to observe whether there is black silver oxide deposits.
另外，我們可以加入少量氨水，觀察是否可以產生黑色的氧化銀沈澱。

■ 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:

學生能了解常見的物質鑑定方法。

Students can understand common methods for identifying substances.

❧ 例題講解 ☙

例題一

說明：學生能理解色層分析法的原理及實驗注意事項。

Students can comprehend the chromatography method's principle and the experimental precautions.

Paper chromatography is a simple method for separation mixtures. First, use a pencil to draw a thin line (as shown in the X and Y lines in the figure on the right) at a proper distance (about 1cm) from the upper and lower edges of the long strip of filter paper. Then, point the sample at Z with a capillary tube and put it into the developing tank containing the appropriate developing solvent (The developing solvent is the solvent that is placed into the developing tank used to develop your TLC plate). Which of the following options are correct about the principle and operation of paper chromatography? (2 items should be selected)

(A) Paper chromatography is to separate mixtures based on the different properties of each component in the mixtures, such as the adsorption force on the filter paper.

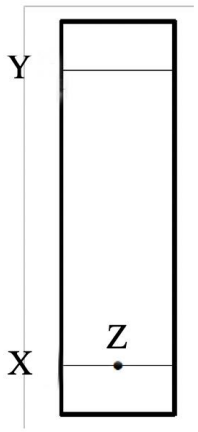
(B) When the sample solution is spotted on the Z of the filter paper with a capillary, it must be continuously contacted for about 10 seconds to increase the sample content.

(C) Sufficient developing solvent must be used to let its liquid level just contact the horizontal line at X.

(D) The expansion can be stopped when the fastest-moving component reaches the fine line at Y.

(E) Changing the developing solvent composition can change the mixture's separation effect.

濾紙層析(濾紙色層分析)是分離混合物的一種簡便方法。首先用鉛筆在長條形濾紙上，距上下緣適當距離處（約 1 公分）各劃一條細線（如右圖 的 X、Y 橫線)；然後用毛細管在 Z 處點好樣品後，再放入裝有適當展開液之展開槽中進行分離。下列有關濾紙層析之原理及操作，哪些選項正確？（應選 2 項）



(A) 濾紙層析(濾紙色層分析)是**利用混合物中各成分物質的性質差異(如對濾紙之吸附力)來達到分離效果。**

(B) 用毛細管將樣品溶液點在濾紙上的 Z 點時，須持續接觸約 10 秒，以提高樣品含量。

(C) 必須使用足量的展開液，使其液面剛好接觸到 X 處之橫線 。

(D) 當移動最快的成分物質到達 Y 處之細線時，即可停止展開 。

(E) 改變展開液的成分可改變混合物的分離效果。

（108 學測 第 30 題）

解題 Solution:

(B) 毛細管僅需短暫接觸濾紙。

(C) 展開液不可碰到 x 線，由最底開始展開。

(D) 展開液到 Y 線即可停止。

(B) The capillary only needs to reach the filter paper briefly.

(C) The elution should not reach line X and should expand from the bottom.

(D) The elution should stop when it reaches the line Y.

Teacher: Do you remember the principle of chromatography?

Student: Chromatographic method separates the substances by using the different adsorption of different substances on the stationary phase.

Teacher: That's correct. How do we spot the sample on the filter paper?

Student: We can use the capillary tube to contact point Z on the filter paper quickly.

Teacher: Wonderful. Where should we add the developing solvent?

Student: We should add below the origin line so we do not reach the horizontal line at X.

Teacher: How do we distinguish whether the developing solvent can be stopped?

Student: The developing solvent reaches the line Y.

Teacher: Excellent. Finally, will changing the developing solvent_influence the separation effect of the mixture?
Student: Yes. Different substances exert different forces on the spreading liquid.

老師： 還記得色層分析法的原理是什麼嗎？
學生： 色層分析法是利用不同物質對固定相的吸附力不同，將物質分離。
老師： 沒錯，要如何將樣品點在濾紙上呢？
學生： 要用毛細管快速的接觸濾紙的 Z 點。
老師： 很棒，展開液要添加到哪個位置呢？
學生： 要添加到原點線以下，所以不能碰到 X 處的橫線。
老師： 要如何判斷可以停止展開呢？
學生： 展開液到達 Y 線時。
老師： 很優秀，最後一個問題，改變展開液會影響混合物的分離效果嗎？
學生： 會，不同物質對展開液的作用力會不同。

例題二

說明：學生能利用沈澱反應將物質分離。
Students can use precipitation reactions to separate substances.

Four solutions are on the attached table: silver nitrate, lead nitrate, barium nitrate, and nickel nitrate. They react with sodium chloride, sodium sulfate, sodium sulfide, and other three solutions, respectively. If the concentration of all solutions is 0.01M, please answer the following questions:

Reagent	$AgNO_3$	$Pb(NO_3)_2$	$Ba(NO_3)_2$	$Ni(NO_3)_2$
NaCl	white precipitate	white precipitate	-	-
Na_2SO_4	-	white precipitate	white precipitate	-
Na_2S	black precipitate	black precipitate	-	black precipitate

A solution contains 0.01M of Ag^+, Pb^{2+}, and Ni^{2+} ions, respectively. If 0.01M of NaCl, Na_2SO_4 and Na_2S solutions are used as reagents to separate Ag+, Pb^{2+}, and Ni^{2+}, which of the following is the order of adding reagents?

(A) NaCl, Na_2SO_4, Na_2S　**(B) Na_2SO_4, NaCl, Na_2S**　(C)NaCl, Na_2S, Na_2SO_4

(D) Na_2SO_4, Na_2S, NaCl　(E) Na_2S, NaCl, Na_2SO_4

附表為硝酸銀、硝酸鉛、硝酸鋇、硝酸鎳等四種溶液，分別與氯化鈉、硫酸鈉、硫化鈉等三種溶液作用的結果，若所有溶液的濃度都是 0.01M，試回答下列問題：

試劑	$AgNO_3$	$Pb(NO_3)_2$	$Ba(NO_3)_2$	$Ni(NO_3)_2$
NaCl	白色沈澱	白色沈澱	-	-
Na_2SO_4	-	白色沈澱	白色沈澱	-
Na_2S	黑色沈澱	黑色沈澱	-	黑色沈澱

有一溶液含有 Ag^+、Pb^{2+}、Ni^{2+}三種離子各 0.01M，若使用均為 0.01M 的 NaCl、Na_2SO_4、Na_2S 溶液作為試劑，使 Ag^+、Pb^{2+}、Ni^{2+}分離，則滴加試劑的順序為下列哪一項？

(A) NaCl、Na_2SO_4、Na_2S

(B) Na_2SO_4、NaCl、Na_2S

(C) NaCl、Na_2S、Na_2SO_4

(D) Na_2SO_4、Na_2S、NaCl

(E) Na_2S、NaCl、Na_2SO_4

（龍騰版 110 上課本（選修化學 I）第一章 第 16 頁 例題 1-2）

解題 Solution:

若溶液中含有 Ag^+、Pb^{2+}、Ni^{2+}三種離子，可將附表簡化為：

試劑	Ag^+	Pb^{2+}	Ni^{2+}
Cl^-	白色沈澱	白色沈澱	-
SO_4^{2-}	-	白色沈澱	-
S^{2-}	黑色沈澱	黑色沈澱	黑色沈澱

(1)加入 Na_2SO_4 時，僅與 Pb^{2+}生成硫酸鉛 $PbSO_4$(s)白色沈澱物。

(2)再加入 NaCl 時，則與 Ag^+生成氯化銀 AgCl(s)白色沈澱物。

(3)最後加入 Na_2S 時，使 Ni^{2+}與 S^{2-}生成硫化鎳 NiS(s)黑色沈澱物。

If the solution contains Ag^+, Pb^{2+}, and Ni^{2+} ions, the attached table can be simplified as:

Reagent	Ag^+	Pb^{2+}	Ni^{2+}
Cl^-	white precipitate	white precipitate	-
SO_4^{2-}	-	white precipitate	
S^{2-}	black precipitate	black precipitate	black precipitate

1. When Na_2SO_4 is added, it only generates lead sulfate, $PbSO_4$ (s), white precipitate with Pb^{2+}.
2. When NaCl is added again, silver chloride, AgCl (s), white sediment is formed with Ag^+.
3. Finally, when Na_2S is added, Ni^{2+} and S^{2-} form nickel sulfide, NiS (s), black sediment.

Teacher: The solution in this question contains three ions: Ag^+, Pb^{2+}, and Ni^{2+}. The table can be simplified as follows.

Reagent	Ag+	Pb^{2+}	Ni^{2+}
Cl^-	white precipitate	white precipitate	-
SO_4^{2-}	-	white precipitate	
S^{2-}	black precipitate	black precipitate	black precipitate

The vertical direction is the reagent we want to add. Which reagent should be added first to produce a precipitation?

Student: Adding Na_2SO_4 first will only form a white precipitate with Pb^{2+}.

Teacher: That's right; now, Ag^+ and Ni^{2+} are left in the solution. Which reagent should be added to produce a precipitation?

Student: When NaCl is added again, it will form a white precipitate with Ag^+.

Teacher: Excellent, what reagents should we add at the end?

Student: Finally, Na_2S is added, which will form a black precipitate with S^{2-}.

Teacher: So what is the correct option for the order of adding reagents?

Student: (B) Na_2SO_4、NaCl、Na_2S

老師： 這題的溶液中含有 Ag^{+}、Pb^{2+}、Ni^{2+}三種離子，所以可將表格簡化成這樣。

試劑	Ag^{+}	Pb^{2+}	Ni^{2+}
Cl^{-}	白色沉澱	白色沉澱	-
SO_4^{2-}	-	白色沉澱	
S^{2-}	黑色沉澱	黑色沉澱	黑色沉澱

縱向是我們要添加的試劑，你們覺得要先加哪個試劑才會產生一種沈澱呢？

學生： 先加 Na_2SO_4，只會與 Pb^{2+}生成白色沈澱物。

老師： 沒錯，現在溶液中剩下 Ag^{+}、Ni^{2+}，再來要加入哪個試劑才會產生一種沈澱呢？

學生： 再來加入 NaCl，會與 Ag^{+}生成白色沈澱物。

老師： 非常棒，最後要加入什麼試劑呢？

學生： 最後加入 Na_2S，會與 S^{2-}生成黑色沈澱物。

老師： 因此正確滴加試劑的順序是哪一個選項？

學生： (B) Na_2SO_4、NaCl、Na_2S。

1-2 反應式的平衡與化學計量
Equilibrium of Reactions and Stoichiometry

■ 前言 Introduction

本節延續高一所教的化學反應式平衡及化學計量，進一步教導學生如何利用氧化數來平衡化學反應式，及判斷限量試劑來計算化學計量與產率。

本節觀念自高一化學延伸，因此希望學生能以更精確的單字進行描述，並搭配句型讓學生確認反應式是否符合所學定律。也希望高程度的學生可以嘗試針對反應式進行更深入的補充。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
reactant	反應物	catalyst	催化劑
resultant/ product	生成物/產物	solid state	固態
coefficient	係數	liquid state	液態
law of conservation of mass	質量守恆定律	gaseous state	氣態
conservation of charge	電荷守恆	aqueous solution	水溶液
stoichiometry	化學計量	limiting reagent	限量試劑
yield	產率	excess reagent	過量試劑
theoretical yield	理論產量	actual yield	實際產量
combination reaction	化合反應	decomposition reaction	分解反應
displacement reaction	置換反應		

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

❶ _____ comply with_____.

例句：The formation of water molecules from hydrogen and oxygen **complies with** the law of conservation of mass.
氫氣和氧氣產生水分子遵守質量守恆定律。

❷ _____, which is in the form of _____, _____.

例句：According to this chemical equation, we can find that hydrogen and oxygen**,** both of **which are in the form of** gas, react to give liquid water.
根據此化學反應式，我們能發現氣態的氫與氣態的氧反應後會產生液態的水。

❸ It is _____that _____.

例句：**It is** by adding ammonia **that** we mainly deal with nitrogen oxides currently.
現今我們會以加入氨氣的方式來處理氮氧化合物。

❹ In the process of redox titration, _____.

例句：**In the process of redox titration,** an acidic potassium permanganate solution of known concentration will react with oxalic acid to produce pink divalent manganese ions and carbon dioxide.
在進行氧化還原滴定的過程中，已知濃度的酸性過錳酸鉀水溶液會與草酸作用產生粉紅色的二價錳離子(Mn^{2+})以及二氧化碳。

■ 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:

學生能平衡反應式以及學會化學計量的計算。

Students can learn to balance chemical equations and acquire skills in stoichiometry calculations.

❧ 例題講解 ☙

例題一

說明：學生能利用「原子不滅」和「電荷守恆」的概念來平衡反應式。

Students can balance the reaction formula via "atom immortality" and "charge conservation."

What is the coefficient of H_2O after balancing the reaction formula:

$NO_3^- + Zn + OH^- + H_2O \rightarrow NH_3 + Zn(OH)_4^{2-}$ (the simplest integer ratio)?

(A)2　(B)3　(C)4　(D)5　**(E)6**

將反應式：$NO_3^- + Zn + OH^- + H_2O \rightarrow NH_3 + Zn(OH)_4^{2-}$

平衡後（最簡單整數比），H_2O 的係數為何？

(A)2　(B)3　(C)4　(D)5　**(E)6**

（翰林版 110 上課本（選修化學 I）第一章　第 31 頁　習題 3）

解題 Solution：

利用「原子不滅」和「電荷守恆」平衡反應式，假設反應係數為：

$aNO_3^- + Zn + bOH^- + cH_2O \rightarrow d\ NH_3 + eZn(OH)_4^{2-}$。

(1)因為反應前 N 和 Zn 原子總數不變：$d = a$，$e = 1$。

(2)平衡H原子：$b + 2c = 4 + 3a$。

(3)平衡O原子：$3a + b + c = 4$。

(4)平衡電荷：$a + b = 2$。

解聯立方程式可得 $a = 0.25$，$b = 1.75$，$c = 1.5$，按比例化成最簡整數比，故平衡反應式為：$NO_3^- + 4\ Zn + 7OH^- + 6\ H_2O \rightarrow 1\ NH_3 + 4\ Zn(OH)_4^{2-}$。

Use the equilibrium reaction formula "atom immortal" and "charge conservation." The reaction coefficient is assumed to be:

$aNO_3^- + Zn + bOH^- + cH_2O \rightarrow d\ NH_3 + eZn(OH)_4^{2-}$

1. Because the total number of N and Zn atoms remains unchanged before the reaction: d = a, e = 1
2. balance H atom: b + 2c = 4 + 3a
3. balance P atom: 3a + b + c = 4
4. balance charge: a + b = 2

Solving the cubic formula, we can get a = 0.25, b = 1.75, c = 1.5, scaled to the simplest integer ratio. Therefore, the balanced reaction equation is:

$$NO_3^- + 4\ Zn + 7\ OH^- + 6H_2O \rightarrow 1\ NH_3 + 4\ Zn(OH)_4^{2-}$$

Teacher:	Which two laws or rules should we use to balance the reaction?
Student:	We can use the law of atomic immortality and the law of charge conservation.
Teacher:	That's right. Observing the equation, when a single element Zn appears, we can assign its coefficient as 1 initially. For the other components, we can assume reaction coefficients as follows: $aNO_3^- + Zn + bOH^- + cH_2O \rightarrow dNH_3 + eZn(OH)_4^{2-}$ Based on the principle that the total number of N and Zn atoms before the reaction remains unchanged, can you know what *d* and *e* are equal to?
Student:	*d* is equal to *a*, and e is 1.
Teacher:	Great. Then, what can we learn if we balance the hydrogen atoms first?
Student:	*b* plus 2 times of *c* is equal to 3d plus 4. Because d is equal to a, b plus 2 times c equals 3a plus 4.
Teacher:	Then, what will we get if we balance the oxygen atoms?
Student:	3 times of *a* plus *b* and *c* is equal to 4.
Teacher:	Then what should we do next?
Student:	Balance charges. The total charge on the left side of the equation must equal the total charge on the right side, and we learn that a plus b equals 2.
Teacher:	The last step is to solve the simultaneous equations and scale them into the simplest integer ratio. What are the reaction coefficients you calculated?

Student: Solving the system of equations yields a = 0.25, b = 1.75, and c = 1.50. Scaling them to the simplest integer ratios, the balanced chemical equation becomes $NO_3^- + 4\ Zn + 7\ OH^- + 6H_2O \rightarrow NH_3 + 4\ Zn(OH)_4^{2-}$.
The coefficient of H_2O after balancing the reaction formula is 6.

老師： 我們應該用哪兩個定律平衡反應式？
學生： 用原子不滅定律和電荷守恆定律平衡。
老師： 沒錯，先觀察式子，僅只有單獨一種元素出現的 Zn 我們可以先訂為 1，而其他可以先假設反應係數為：$aNO_3^- + Zn + bOH^- + cH_2O \rightarrow d\ NH_3 + eZn(OH)_4^{2-}$
根據反應前 N 和 Zn 原子總數不變，可以知道 d 和 e 等於什麼？
學生： d 等於 a，e 等於 1。
老師： 很棒，我們先平衡氫原子，可以知道什麼？
學生： b 加 2c 等於 4+3d。因為 d 等於 a，b 加 2c 等於 4+3a。
老師： 再來平衡氧原子，可以知道什麼？
學生： 3a 加 b 加 c 等於 4。
老師： 非常棒，最後還要平衡什麼？
學生： 平衡電荷，式子左邊的總電荷數要等於右邊的總電荷數，可以知道 a 加 b 等於 2。
老師： 最後一步解聯立方程式，按比例化成最簡整數比，你們算出來反應係數是什麼呢？
學生： 解聯立方程式可得 a = 0.25，b = 1.75，c = 1.5，按比例化成最簡整數比，故平衡反應式為：$NO_3^- + 4\ Zn + 7\ OH^- + 6H_2O \rightarrow NH_3 + 4\ Zn(OH)_4^{2-}$。
因此，平衡後 H2O 的反應係數為 6。

例題二

說明：學生能從化學反應式中反應物的用量判斷出何者為限量試劑。
Students can determine the limiting reagent from the quantities of reactants in a chemical reaction.

Potassium superoxide is often used to fill the respirator, which can produce chemical reactions. Its reaction formula is as follows:

$$4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$$

The oxygen released from the reaction can provide breathing for the wearer in the pit, under the water, on the mountain, or flying high above the ground. If the reaction between 0.16 mol KO_2 and 0.10 mol CO_2 is complete, which of the following statements are correct?

(A) KO_2 is a limited reagent.
(B) About 4.8 g of oxygen will be generated.
(C) The higher coefficient in the chemical reaction formula is always the limited reagent.
(D) The one used up first in a chemical reaction is a limited reagent.
(E) The substance participating in the reaction with less mass may not be the limited reagent.

超氧化鉀常用於充填在呼吸面罩中，能發生反應，其反應式如下：

$$4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$$

反應所釋放出的氧氣，可提供在礦坑、水面下、高山上或高空飛行等之配戴者呼吸。當 0.16 mol 的 KO_2 與 0.10 mol 的 CO_2 完全反應完畢時，試問下列敘述哪些正確？

(A) KO_2 為限量試劑。
(B) 將生成氧氣約 4.8 克。
(C) 化學反應式中係數較大者恆為限量試劑。
(D) 化學反應中最先被使用完畢者為限量試劑。
(E) 實際參與反應的物質，質量較少者不一定為限量試劑。

（本題目改自南一版 110 上課本（選修化學 I）第一章 第 41 頁 多選題第 1 題）

解題 Solution：

	$4KO_2$	$+ 2CO_2$	$\rightarrow 2K_2CO_3$	$+ \quad 3O_2$
原有莫耳數	0.16	0.1		
變化的莫耳數	-0.16	-0.08	+0.08	+ 0.12
反應後莫耳數	0	0.02	0.08	0.12

最先被使用完畢者為限量試劑，所以 KO_2 為限量試劑，生成氧氣 3.84 克。

	$4KO_2$	$+ \quad 2CO_2$	$\rightarrow \quad 2K_2CO_3$	$+ \quad 3O_2$
original mole	0.16	0.1		
mole of change	-0.16	-0.08	+0.08	+ 0.12
mole after reaction	0	0.02	0.08	0.12

The one used up first in chemical reaction is a limited reagent. KO_2 is the limited reagent, which generates 3.84 grams of oxygen.

Teacher: How can we tell the limited reagent from others?

Student: The reactant completely consumed first in the chemical reaction is the limited reagent.

Teacher: Can a limited reagent be directly judged by the reaction coefficient or quality?

Student: No, divide the molar number of each reactant by its coefficient; the smaller the value is, the limit reagent is.

Teacher: Great. Which one is the limited reagents in this question?

Student: KO_2 is a limited reagent. KO_2 molar divided by its coefficient 0.16/4 is 0.04, and CO_2 molar divided by 0.1/2 is 0.05. As a result, the value of KO_2 is relatively small, so it is a limited reagent.

Teacher: Excellent. Next, we can infer from the actual quantities involved in the reaction using the coefficient ratios to deduce the amount of product generated. Therefore, when the limiting reagent is consumed at 0.16 mol and given the coefficient ratio of KO_2 to oxygen is 4:3. How many moles of oxygen are produced? How many grams?

Student: The oxygen produced was 0.12 moles, which will be 3.84 grams.

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

Student: (A) (D) (E).

老師： 要如何判斷何者為限量試劑呢？

學生： 化學反應中最先被使用完畢的反應物為限量試劑。

老師： 沒錯，限量試劑能直接用反應式係數或質量多寡判斷嗎？

學生： 不行，要將各反應物的莫耳數除以其係數，數值最小的則為限量試劑。

老師： 非常棒，這一題中何者為限量試劑？

學生： KO_2 是限量試劑，因為 KO_2 莫耳數除以其係數 0.16/4 是 0.04，CO_2 莫耳數除以其係數 0.1/2 是 0.05，KO_2 的值比較小所以是限量試劑。

老師： 真聰明，接著要推斷生成物會產生多少量，我們可以由實際參與反應的量及係數比來推論，因此當限量試劑被用掉了 0.16 mol，由 KO_2 和氧氣的係數比 4:3，求出生成的氧氣為多少莫耳？多少克呢？

學生： 生成的氧氣為 0.12 莫耳，3.84 克。

老師： 很好，因此這一題的答案是甚麼？

學生： (A)(D)(E)。

1-3 反應熱的種類與性質
Types and Properties of Heat of Reaction

■ 前言 Introduction

首先教師列舉常見反應熱的種類，說明標準莫耳生成熱的定義及表示法，讓學生了解影響反應熱的各項因素，接著利用赫斯定律由已知反應熱的反應式，求取特定反應式未知的反應熱。

本節中學生被期望能觀察熱含量變化圖表後，說明熱反應的種類，因此語言上會以說明及指示用途的句構為主。另外，反應熱與生成熱的對應關係則會需要學生使用具有對照、對比功能的句型進行說明。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
heat content	熱含量	thermochemical equation	熱化學方程式
heat of reaction	反應熱	molar reaction heat	莫耳反應熱
standard status	標準狀態	standard molar reaction heat	標準莫耳反應熱
exothermic reaction	放熱反應	heat of molar formation	莫耳生成熱
endothermic reaction	吸熱反應	standard molar heat of formation	標準莫耳生成熱
thermochemistry	熱化學	Hess's law/ the law of additivity of reaction heat	赫斯定律／反應熱加成性定律

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

❶ _____ is called_____.

例句：In a chemical reaction, the difference between the sum of the heat content of the products and the sum of the heat content of the reactants **is called** the heat of reaction.
化學反應中，生成物的熱含量總和與反應物的熱含量總和之差值，稱為反應熱。

❷ As is shown in the graph, _____.

例句：**As is shown in the graph,** when the total heat content of the reactants is greater than the total heat content of the products, this is an exothermic reaction.
如圖所示，當反應物的總熱含量大於生成物的總熱含量時，此為放熱反應。

❸ On one hand, _____. On the other hand, _____.

例句：Thermal reactions are divided into two types. **On one hand,** when the total heat content of the reactants is greater than the total heat content of the products, this is an exothermic reaction. **On the other hand,** when the total heat content of the reactants is less than the total heat content of the products, which is an endothermic reaction.
熱反應分為兩種，一方面，當反應物的總熱含量大於生成物的總熱含量時，此為放熱反應；另一方面，當反應物的總熱含量小於生成物的總熱含量時，此為吸熱反應。

■ 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:

學生能了解熱化學方程式的書寫方式及在化學反應式中能量的變化。

Students can comprehend the writing style of thermochemical equations and the changes in energy within chemical reactions.

❧ 例題講解 ☙

例題一

說明：學生能學會計算莫耳生成熱。

Students can learn to calculate the heat of formation.

Please check the table below to know the molar heat of the formation of glucose at 25 °C and 1 atm, and write the corresponding thermochemical equation. How many calories need to be absorbed or released to produce 270 g of glucose? ($C_6H_{12}O_6$ = 180)

請查下表以得知 25 ℃、1atm 時葡萄糖的莫耳生成熱，並寫出相對應的熱化學反應式。若欲生成 270 g 的葡萄糖，需要吸收或放出多少熱量？（$C_6H_{12}O_6$＝180）

一氧化碳	酒精	乙烯	葡萄糖	碳酸鎂	甲烷	一氧化氮	水蒸氣	水
$CO(g)$	$C_2H_5OH(l)$	$C_2H_4(g)$	$C_6H_{12}O_6(s)$	$MgCO_3(s)$	$CH_4(g)$	$NO(g)$	$H_2O(g)$	$H_2O(l)$
− 110.5	− 277.7	52.3	− 1260	− 1095.8	− 74.8	90.2	− 241.8	− 285.8

（本題目改自南一版 110 上課本（選修化學 I）第一章 第 29 頁 例題 1-1）

解題 Solution：

$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$　$\Delta H = -1260$ kJ

葡萄糖的莫耳數＝1.50 mol

需放熱 1260 kJ／mol×1.50 mol＝1890 kJ

$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$　$\Delta H = -1260$ kJ

The number of moles of glucose ＝ 1.50 mol

Need to exotherm 1260 kJ/mol×1.50 mol＝1890 kJ

Teacher: What should we do before figuring out how many calories we need to absorb or give out to produce 270 grams of glucose?

Student: We should write the chemical equation for the production of glucose.

$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$

Teacher: That's right. Based on the thermochemical equation, how to calculate the heat of reaction based on the data in the table.

一氧化碳	酒精	乙烯	葡萄糖	碳酸鎂	甲烷	一氧化氮	水蒸氣	水
$CO(g)$	$C_2H_5OH(l)$	$C_2H_4(g)$	$C_6H_{12}O_6(s)$	$MgCO_3(s)$	$CH_4(g)$	$NO(g)$	$H_2O(g)$	$H_2O(l)$
− 110.5	− 277.7	52.3	− 1260	− 1095.8	− 74.8	90.2	− 241.8	− 285.8

Student: The sum of the heat content of the products minus the sum of the heat content of the reactants, which for this question will be

−1260 kilojoule−0 kilojoule = −1260 kilojoule.

Teacher: Great, so the molar heat of the formation of glucose is -1260 kilojoule. Is it endothermic or exothermic?

Student: Exothermic.

Teacher: Yes, write the corresponding thermochemical equation.

Student: $6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$　$\Delta H = -1260$ kJ

Teacher: We got the heat of formation per mole of glucose. How many moles is 270g of glucose?

Student: 270 g / 180 g mol =1.5 mole

Teacher: That's right. And we know that the production of 1 mol of glucose releases −1260 kJ. Therefore, the production of 270 g of glucose, which is equivalent to 1.5 mole, requires the absorption or release of how much heat?

Student: 1260 kJ／mole×1.50 mole＝1890 kJ, 1890 kilojoules of heat are given out.

老師： 在算出生成 270 g 的葡萄糖，需要吸收或放出多少熱量之前首先我們要先做什麼事？

學生： 寫出生成葡萄糖的化學反應式。$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$

老師： 沒錯，根據熱化學方程式，我們如何寫出此反應的反應熱？

學生： 生成物的熱含量總和減反應物的熱含量總和，因此此題的反應熱為−1260 千焦耳。

老師： 很好，所以葡萄糖的莫耳生成熱為−1260 千焦耳，為吸熱還放熱？

學生： 放熱。

老師： 對的，寫出相對應的熱化學反應式。

學生： $6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s) \quad \Delta H = -1260\ kJ$

老師： 我們已經有葡萄糖每莫耳的生成熱，270g 的葡萄糖為幾莫耳？

學生： 270 克/(180 克/莫耳) =1.5 莫耳。

老師： 沒錯，而我們知道每生成 1 莫耳 的葡萄糖會放出 −1260 千焦耳，因此生成 270 g 的葡萄糖也就是 1.5 莫耳，需要吸收或放出多少熱量？

學生： 1260 kJ／mol×1.50 mol＝1890 kJ，放出 1890 千焦耳的熱量。

例題二

說明：了解赫斯定律的計算。

Students can understand the calculation of Hess's law.

(1) $4NH_3(g)+3O_2(g) \rightarrow 2N_2(g)+6H_2O(l)$　$\Delta H=-1530$ kJ

(2) $N_2O(g)+H_2(g) \rightarrow N_2(g)+H_2O(l)$　$\Delta H=-367$ kJ

(3) $H_2(g)+1/2O_2(g) \rightarrow H_2O(l)$　$\Delta H=-286$ kJ

How many kJ is the heat of the reaction of　$2NH_3(g)+3N_2O(g) \rightarrow 4N_2(g)+3H_2O(l)$?

(1) $4NH_3(g)+3O_2(g) \rightarrow 2N_2(g)+6H_2O(l)$　$\Delta H=-1530$ kJ

(2) $N_2O(g)+H_2(g) \rightarrow N_2(g)+H_2O(l)$　$\Delta H=-367$ kJ

(3) $H_2(g)+1/2O_2(g) \rightarrow H_2O(l)$　$\Delta H=-286$ kJ

試求：$2NH_3(g)+3N_2O(g) \rightarrow 4N_2(g)+3H_2O(l)$ 的反應熱為若干 kJ？

（本題目選自龍騰版 110 上講義（選修化學 I）第一章 第 39 頁 範例 5）

解題 Solution：

(1) 乘以 0.5，　$2NH_3(g)+3/2O_2(g) \rightarrow N_2(g)+3H_2O(l)$　$\Delta H=-1530 * 0.5$

(2) 乘以 3，　$3N_2O(g)+3H_2(g) \rightarrow 3N_2(g)+3H_2O(l)$　$\Delta H=-367 * 3$

+) (3) 乘以(−3)，$3H_2O(l) \rightarrow 3H_2(g)+3/2O_2(g)$　$\Delta H=286 * 3$

$$2NH_3(g)+3N_2O(g) \rightarrow 4N_2(g)+3H_2O(l)$$

$$\Delta H=-1530 * 0.5+(-367 * 3)+286 * 3=-1008 \text{ kJ}$$

(1) multiply by 0.5, $2NH_3(g)+3/2O_2(g) \rightarrow N_2(g)+3H_2O(l)$　$\Delta H=-1530 * 0.5$

(2) multiply by 3, $3N_2O(g)+3H_2(g) \rightarrow 3N_2(g)+3H_2O(l)$　$\Delta H=-367 * 3$

+) (3) multiply by (−3), $3H_2O(l) \rightarrow 3H_2(g)+3/2O_2(g)$　$\Delta H=286 * 3$

$$2NH_3(g)+3N_2O(g) \rightarrow 4N_2(g)+3H_2O(l)$$

$$\Delta H=-1530 * 0.5+(-367 * 3)+286 * 3=-1008 \text{ kJ}$$

Teacher: By reading the title, we can combine the heat of the reaction from the known thermochemical equations. The heat of the reaction of a thermochemical equation can be obtained by summing up the heat in different ways. What law will such a reaction obey?

Student: Hess's law.

Teacher: That's right. The requirements of the title, how can we apply Hess's law to calculate the heat of the reaction accordingly?

Student: Because the desired balanced reaction is $2NH_3\ (g) + 3N_2O\ (g) \rightarrow 4N_2\ (g) + 3H_2O\ (l)$, oxygen gas must be eliminated, and N_2O must be present in 3 moles while $NH_3\ (g)$ must be present in 2 moles.

So, first multiply formula (1) by 0.5 to cancel out the oxygen term when combined with equation (3), formula (2) by 3, and formula (3) by -3. We can get the answer after we calculate their respective heat of reaction and find the sum, which is the heat of reaction for this question.

(1) multiply by 0.5, $2NH_3(g) + 3/2O_2(g) \rightarrow N_2(g) + 3H_2O(l)$ $\quad \Delta H = -1530 * 0.5$

(2) multiply by 3, $3N_2O(g) + 3H_2(g) \rightarrow 3N_2(g) + 3H_2O(l)$ $\quad \Delta H = -367 * 3$

+) (3) multiply by (-3), $3H_2O(l) \rightarrow 3H_2(g) + 3/2O_2(g)$ $\quad \Delta H = 286 * 3$

$$2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(l)$$

$$\Delta H = -1530 * 0.5 + (-367 * 3) + 286 * 3 = -1008\ kJ$$

So, the heat of reaction of $2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(l)$ is -1008 kJ

老師：從題目來看我們能從已知的熱化學方程式組合出欲求的反應熱，而一個熱化學方程式的反應熱可由不同途徑，再經由熱量的加總求得，這樣的反應會遵守什麼定律？

學生：赫斯定律。

老師：沒錯，因此根據題目的要求，我們該如何應用赫斯定律計算出欲求的反應熱？

學生：因為最終欲求的反應式為 $2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(l)$，因此須將氧氣消去，且 N_2O 需有 3 莫耳，$NH_3(g)$需有 2 莫耳，所以先將式(1)乘以 0.5 為了和式(3)消去氧，式(2)乘以 3，式(3)乘以-3，算出其各自的反應熱並求其總和，即為此題的反應熱。

(1) 乘以 0.5，$2NH_3(g) + 3/2O_2(g) \rightarrow N_2(g) + 3H_2O(l)$ $\quad \Delta H = -1530 * 0.5$

(2) 乘以 3，$3N_2O(g) + 3H_2(g) \rightarrow 3N_2(g) + 3H_2O(l)$ $\quad \Delta H = -367 * 3$

+) (3) 乘以(-3)，$3H_2O(l) \rightarrow 3H_2(g) + 3/2O_2(g)$ $\quad \Delta H = 286 * 3$

$$2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(l)$$

$$\Delta H = -1530 * 0.5 + (-367 * 3) + 286 * 3 = -1008\ kJ$$

因此 $2NH3(g) + 3N2O(g) \rightarrow 4N2(g) + 3H2O(l)$的反應熱為 -1008 kJ.

★ 主題二 氣體 ★
Gas

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■ 前言 Introduction

本章首先認識氣體的性質，包括壓力單位、氣體的運動模型與不同種類的水銀氣壓計的計算方法，接著介紹氣體各項定律及應用，再來引導學生理解氣體分子的運動模型，比較真實氣體與理想氣體之間的差異，進而認識道耳頓的分壓定律，深入探討混合氣體之間各氣體分壓。

語言方面，除了與氣體相關的的單字外，會以對比對照的方式，讓學生學習如何介紹與比較氣體性質與氣壓在日常生活中的應用，藉此協助學生進行學科知識的探究與結論。

2-1 氣體性質
Gas Properties

■ 前言 Introduction

此小節教師引導學生氣體的性質，並透過氣體分子的運動模型，瞭解造成氣體壓力的原因，再藉由開口式壓力計和閉口式壓力計判斷和計算氣體壓力的大小。

本節中教師應先讓學生認識基本單字，再配合介紹用的句型，讓學生試著對比氣體性質與壓力計的差異。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
barometer	氣壓計	atmospheric pressure	大氣壓
expansion	膨脹性	Pascal	帕斯卡
fluidity	流動性	compressibility	壓縮性
vacuum	真空	closed-tube manometer	閉口式壓力計
open-tube manometer	開口壓力計	International System of Units	國際單位系統

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

❶ _____ have/has an impact on_____.

例句：The flow of the atmosphere illustrates the fluidity of gas, which **has an impact on** the daily life of human beings.

大氣的流動說明了氣體的流動性，它影響人類的日常生活。

❷ ____ be related to _____.

例句：The flow of the atmosphere **is** closely **related to** changes in the weather and environmental problems.

大氣的流動與天氣的變化和環境的問題息息相關。

❸ _____ be abbreviated to _____.

例句：The unit of pressure adopted by the International System of Units is Pascal, which can **be abbreviated to** Pa.

國際單位系統採用的壓力單位為帕斯卡，簡稱為帕。

❹ There are two types of _____. One is _____, the other is _____.

例句：The tool for measuring the gas pressure in a closed container is called a manometer, and **there are two types of** them. **One is** a closed-tube manometer, while **the other is** an open-tube manometer.

測量密閉容器內的氣體壓力的工具稱為壓力計，而壓力計分為兩種。一種為閉口式壓力計，而另一種是開口式壓力計。

■ 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:

學生能了解氣體的性質及氣體壓力的測量。

Students can understand the properties of gas and the measurement of gas pressure.

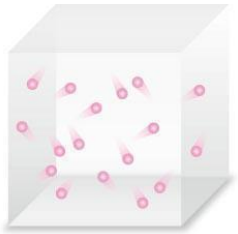
❧ 例題講解 ☙

例題一

說明：學生能從微觀了解氣體壓力的形成原因。

Students can understand the causes of gas pressure from a microscopic perspective.

The figure on the right shows the model of the free movement of gas particles in a closed container. This model expresses that the pressure of gas comes from the concept that gas particles collide with the container wall. According to this particle motion model, which of the following statements are correct?



(A) The magnitude of the pressure depends on the number of impacts per unit time and the impact force.

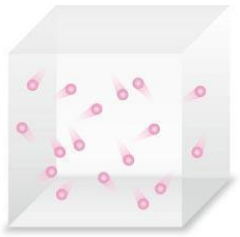
(B) At constant volume, the gas pressure increases when the number of impactor wall collisions per unit time increases.

(C) At absolute zero, ideal gas particles still have kinetic energy.

(D) When the temperature rises, the number of collisions per unit time and the impact force remain unchanged, so the gas pressure also remains unchanged.

(E) At the same temperature, the speed of gas particles is not exactly the same.

右圖為密閉容器中氣體粒子自由移動的模型，此模型表達氣體的壓力是來自氣體粒子碰撞容器壁的概念。依據此粒子運動模型，下列敘述哪些正確？



(A) 壓力的大小取決於每單位時間撞擊器壁的次數及撞擊力道。

(B) 定容下，單位時間碰撞器壁次數增大，則氣體壓力增大。

(C) 於絕對零度時，理想氣體粒子仍具有動能。

(D) 當溫度升高，單位時間碰撞器壁次數及碰撞力道均不變，因此氣體壓力也不變。

(E) 同一溫度時，氣體粒子的速率並非完全相同。

（南一版 110 上課本（選修化學 I）第二章 習題 多選題第 2 題）

Teacher: From a microscopic point of view, how is the pressure of gas in a closed container generated?

Student: It is through the number and force of the gas hitting the wall of the container per unit of time.

Teacher: That's right, how would the gas pressure change if the number of hits to the wall of the vessel increases?

Student: It will increase.

Teacher: Great, what happens to the pressure if you raise the temperature?

Student: It will increase because the rate of motion of the gas will increase and so will the frequency at which it hits the walls of the vessel.

Teacher: What about at an absolute temperature of zero?

Student: The gas may have no pressure because the gas particles do not move freely, they do not collide with the walls of the container to create pressure.

Teacher: Excellent, so at the same temperature, do the gas particles move at the same rate?

Student: No, gas particles collide with each other in the container, which will cause some particles to be faster and some slower. Therefore, at the same temperature, the speed of gas particles is not the same.

Teacher: Very good, so what are the correct options for this question?

Student: The correct options are (A) (B) (E).

老師： 以微觀來看，氣體在密閉容器中的壓力是如何產生的呢？

學生： 氣體在單位時間撞擊容器器壁的次數和力道。

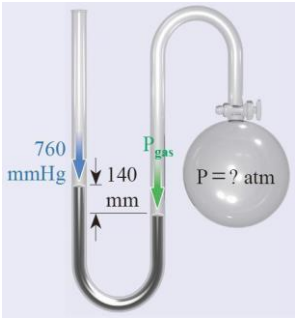
老師： 沒錯，如果撞擊器壁的次數增加，氣體壓力會如何改變？

學生： 增加。
老師： 很棒，如果將溫度升高，壓力會麼改變呢？
學生： 增加，因為氣體的運動速率會增加，撞擊器壁的頻率也增加。
老師： 如果在絕對零度時呢？
學生： 氣體可能沒有壓力吧，因為氣體粒子不會自由移動，不會碰撞容器壁而產生壓力。
老師： 很聰明，那麼在同一溫度時，氣體粒子會有相同的運動速率嗎？
學生： 不會，氣體粒子在容器內彼此碰撞，會造成有些粒子速率快，有些速率慢，因此同一溫度，氣體粒子的速率並非完全相同。
老師： 太棒了，因此此題的正確選項有哪些？
學生： (A) (B) (E)。

例題二

說明：學生能藉由壓力計的高度差計算氣體壓力。
Students can calculate the gas pressure by the height difference of the manometer.

We know that the atmospheric pressure is 760 mmHg. As shown in the right figure, the pressure of a gas is measured with an open-tube manometer. The height difference between the left and right mercury columns is 140 mm. How much mmHg is the pressure of this gas? How many atms are equivalent?



已知大氣壓力為 760 mmHg，如右圖所示，以開口式水銀壓力計測量某氣體的壓力，左、右管水銀柱的高度差為 140 mm，求此氣體的壓力為多少 mmHg？相當於多少 atm？

（翰林版 110 上課本（選修化學 I）第二章 第 10 頁 範例 2-2）

Teacher: Which side is at a higher pressure in the picture?
Student: The right side. This is because the mercury level on the right is lower than that on the left.
Teacher: That's right, how much mmHg is the right side bigger (or larger) than the left side?
Student: 140mmHg.
Teacher: So how should we figure out the gas pressure on the right?

Student: 760 mmHg plus 140 mmHg equals 900 mmHg.
Teacher: The answer is correct, how to convert the 900 mmHg unit into atm?
Student: Because the atmospheric pressure is 760 mmHg, after it is divided by 760 mmHg, we will learn that 900 mmHg is equal to 1.18atm.

老師： 從圖中哪邊的壓力比較大？
學生： 右邊，因為右邊的汞柱液面低於左邊。
老師： 沒錯，右邊比左邊大多少 mmHg 呢？
學生： 140 mmHg。
老師： 所以我們應該如何算出右邊的氣體壓力？
學生： 760 mmHg 加 140 mmHg 等於 900 mmHg。
老師： 答對了，那 900mmHg 單位換成 atm 要如何換算呢？
學生： 因為一大氣壓是 760mmHg，所以要除以 760mmHg，900mmHg 等於 1.18atm。

2-2 氣體定律
Gas Law

■ 前言 Introduction

在本小節教師帶學生探討了氣體的性質並討論氣體的壓力、體積、莫耳數以及溫度之間的關係來讓學生更了解氣體的運作模式。

語言方面，學生也因此需要學習用來表示探究與解釋的句型，例如表達「因為…」及「用來解釋…」。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
air column	氣柱	mercury column	汞柱
liquid level	液面	Boyle's law	波以耳定律
closed end	封閉端	atmospheric pressure	大氣壓
gas expansion rate	氣體膨脹率	Charles's law	查理定律
extrapolation	外插法	absolute temperature scale	絕對溫標
Celsius	攝氏溫度	Avogadro's law	亞佛加厥定律

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

❶ With _____, _____.

例句：**With** J-shaped tubes, British scientist Boyle explored the relationship between the pressure and volume of a quantitative gas in a closed container under a fixed temperature.
英國科學家波以耳利用 J 型管探討在固定溫度的條件下，觀察氣體在密閉容器中的壓力與體積之間的關係。

❷ _____, which means _____. = _____, meaning _____.

例句：When the volume of the gas column is 60mL, the difference in height between the two ends of the mercury column is zero**, which means** that the gas pressure at the end of the closed column is in equilibrium with the atmospheric pressure outside.
當氣柱體積為 60mL 時，兩端汞柱液面的高度差為零，表示封閉管柱端的氣體壓力與外界的大氣壓力達平衡狀態。

❸ _____in explanation of _____.

例句：We can use Boyle's law **in the explanation of** human respiration.
我們可以用波以耳定律來解釋人類的呼吸作用。

❹ In conclusion, _____.

例句：**In conclusion,** under the same temperature and pressure, the same volume of gas contains the same number of molecules, that is, the gas volume is proportional to the number of moles.
結論就是，同溫、同壓下，相同體積的氣體含有相同的分子數，即氣體體積與莫耳數成正比。

■ 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:

學生能了解氣體性質之間的關係。

Students can understand the relationship between the properties of gases.

❧ 例題講解 ☙

例題一

說明：學生能了解氣體在定溫、定壓下，體積與莫耳數的關係。

Students can understand the relationship between the volume and the number of moles of a gas at a constant temperature and pressure.

There is a container containing two diatomic gas molecules X_2 and Y_2, the molar ratio of which is 1:2, reacting at a constant temperature and pressure, after the reaction is completed, the volume becomes 1/2 of the original volume, if the reaction is only A product, and it is a gas, what is the possible molecular formula of the gas product?

(A) X_2Y

(B) XY

(C) XY_2

(D) X_3Y_2

(E) X_2Y_3

有一容器裝有 X_2、Y_2 兩種雙原子的氣體分子，其莫耳數比為 1:2，在定溫、定壓下反應，反應完成後體積變為原來的 1/2，若該反應只有一種產物，並且為氣體，則該氣體產物的分子式可能為何？

(A) X_2Y

(B) XY

(C) XY_2

(D) X_3Y_2

(E) X_2Y_3

（110 指考化學科 第 5 題）

Teacher: To find the molecular formula of the gas product of this reaction, what can we do first?

Student: We should assume the desired molecular formula is X_aY_b.

Teacher: That's right, then we need to find out the relationship between the reactant and the product in the chemical equation to derive the molecular formula of the product, so how to write the chemical equation based on our assumptions?

Student: With the law of atomic indestructibility and mass conservation, the chemical equation can be written as $\frac{a}{2}\ X2 + \frac{b}{2}\ Y_2 \rightarrow\ X_aY_b$.

Teacher: Then we can write the equation after the reaction as

$$\begin{array}{l} aX2 + bY2 \rightarrow 2XaYb \\ \ \ 1 \quad\ \ 2 \\ -ma \ -mb \quad +2m \\ \hline 1\text{-}ma \ \ 2\text{-}mb \ \ \ 2m \end{array}$$

Originally a total of 3 moles reacted leaving 1/2 of the original amount, and in other words, 1.5 moles are left. What equation can we formulate?

Student: 1-ma+2-mb+2m=1.5, the simplification of which will be (a+b-2)m=1.5.

Teacher: Very good, then let's assume that X2 is a limited reagent, so 1-ma=0, m=1/a. What will be obtained by substituting (a+b-2)m=1.5?

Student: 1+(b-2) * 1/a=1.5, and a=2b-4.

Teacher: That's right, and because a and b must be positive integers, we can get a=2, b=3, so a:b=2:3. If Y2 is assumed to be a limited reagent, it does not meet the answer, so the answer is (E).

老師： 為了求出此反應的氣體產物分子式，首先我們能先做什麼事？

學生： 假設所求的分子式為 X_aY_b。

老師： 沒錯，接著我們要找出化學反應式中反應物與產物的關係來推得其產物之分子式，因此根據我們的假設該如何寫出化學反應式？

學生： 根據原子不滅及質量守恆定律，可將反應式寫成 $\frac{a}{2}\ X2 + \frac{b}{2}\ Y_2 \rightarrow\ X_aY_b$

老師： 接著我們可以將反應後的方程式寫成

$$\begin{array}{l} aX2 + bY2 \rightarrow 2XaYb \\ \ \ 1 \quad\ \ 2 \\ -ma \ -mb \quad +2m \\ \hline 1\text{-}ma \ \ 2\text{-}mb \ \ \ 2m \end{array}$$

原本總共 3 莫耳反應後剩下原來的 1/2，所以剩下 1.5 莫耳，我們可以列出什麼方程式？

學生： 1-ma+2-mb+2m=1.5，化簡後得(a+b-2)m=1.5。

老師： 很好，接著我們先假設 X2 是限量試劑，因此 1-ma=0，得 m=1/a，代入(a+b-2)m=1.5 會得到什麼？

學生： 1+(b-2) * 1/a=1.5，得 a=2b-4。

老師： 沒錯，又因為 a 和 b 須為正整數，則我們可得 a=2, b=3，因此 a:b=2:3，若假設 Y2 為限量試劑則不符合答案，故答案選(E)。

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 neon light commonly used in advertising signs is a lamp containing neon gas, and the neon gas filled in the lamp tube can emit red light after passing through an electric current. Bending the glass tube into the required characters or patterns, then installing the electrodes, taking out the air in the glass tube, and then filling it with neon gas, it can become a red neon light. It is known that the neon used in neon lamps has a pressure of 2.4 mmHg in a 0.50 L container. At the same temperature, when the gas is completely injected into a 0.30 L neon lamp glass column, how much pressure will it produce?

(A) 4 (mmHg)
(B) 5 (mmHg)
(C) 6 (mmHg)
(D) 7 (mmHg)

常用於廣告招牌的霓虹燈是一種內含氖氣的燈，填充在燈管中的氖氣通入電流後能發出紅光。將玻璃管彎製成所需要的文字或花紋圖案後裝上電極，並把玻璃管內的空氣抽出，再充進氖氣，即可成為紅色的霓虹燈。已知使用於霓虹燈的氖在體積 0.50 L 容器內，壓力為 2.4 mmHg，在相同溫度下，當此氣體完全注入一體積為 0.30 L 的霓虹燈玻璃管柱內時，將會產生多少壓力？

(A) 4 (mmHg)

(B) 5 (mmHg)

(C) 6 (mmHg)

(D) 7 (mmHg)

（翰林版 110 上課本（選修化學 I）第二章 第 13 頁 範例 2-3）

Teacher: To find out the pressure generated in the 0.3L neon tube, I can see that what I want to discuss in this topic is the relationship between volume and pressure, and from the laws that we have learned, which one is about volume and pressure?

Student: Boyle's law. PV is equal to a constant value, and pressure is inversely proportional to volume.

Teacher: That's right, what else is needed if it complies with Boyle's Law?

Student: The gas must be in constant temperature and quantitative in a closed system.

Teacher: Therefore, based on the known information on the topic, what formula can we list to obtain the desired pressure?

Student: P1V1=P2V2, 2.4 * 0.5=P2 * 0.3. P2=4 (mmHg).

老師： 為了求出在 0.3L 的霓虹燈管產生的壓力，我可以看出在此題目中想要探討的是體積及壓力的關係，而由我們所學的氣體定律之中，哪種定律是在探討體積及壓力的關係？

學生： 波以耳定律，PV=定值，壓力與體積成反比。

老師： 沒錯，符合波以耳定律還需要什麼條件？

學生： 氣體必須要在密閉環境中定溫、定量。

老師： 因此由題目已知的資訊，我們可列出什麼式子來求得所求之壓力？

學生： P1V1=P2V2，2.4 * 0.5=P2 * 0.3，因此 P2=4 (mmHg)。

2-3 理想氣體方程式
Ideal Gas Equation

■ 前言 Introduction

此小節教師引導學生認識氣體相關學說的發現，認識理想氣體方程式的計算與應用，並比較真實氣體與理想氣體之間的差異。

語言教學部分可以利用過去學過的比較級和最高級句型，來進行不同氣體的密度、重量、壓力等之間的比較。在解釋理想氣體方程式的公式時，建議先用中文進行解釋，接著再用英文進行解釋，這樣有助於學生理解兩種語言之間的對應關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
ideal gas equation	理想氣體方程式	Boyle's law	波以耳定律
constant temperature	定溫	Charles-Gay-Lussac law	查克-給呂薩克定律
constant pressure	定壓	Avogadro's law	亞佛加厥定律
quantitation	定量	standard temperature and pressure	標準溫壓(STP)

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

❶ deduce _____ from _____.

例句：We **deduce** the ideal gas equation **from** Boyle's law, Charles-Gay-Lussac law, and Avogadro's law.
我們由波以耳定律、查克-給呂薩克定律和亞佛加厥定律推導出理想氣體方程式。

❷ Under the condition of_____, _____.

例句：**Under the condition of** the same temperature and same pressure, gas molecular weight is proportional to gas density.
在同溫、同壓的條件下，氣體分子量與氣體密度成正比。

❸ _____ be viewed as _____. =_____ be considered _____. =_____be regarded as _____.

例句：The property of ideal gas is assumed to be: with mass, extremely small volume of gas particles, and no force between gas particles, and the collision effect in the vessel wall can **be regarded as** a completely elastic collision.
理想氣體的性質假設為：具有質量、氣體粒子體積極小、氣體粒子間無作用力，於器壁內的碰撞作用，可視為完全彈性碰撞。

❹ at the same _____, _____.

例句：**At the same** temperature and pressure, the molecular weight is proportional to the density.
同溫同壓時，分子量和密度成正比。

■ 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:

學生能理解理想氣體方程式，並理解理想氣體與真實氣體的差異。

Students can understand the ideal gas equation and understand the difference between ideal gas and real gas.

❧ 例題講解 ☙

例題一

說明：學生能利用理想氣體方程式比較不同氣體的密度重量、壓力等。

Students can use the ideal gas equation to compare the density, weight, pressure, etc. of different gases.

There are four kinds of gases: H_2, CH_4, O_2, and NH_3. Which of the statements are correct? (Atomic weight: C=12, N=14, O=16)

(A) At the same temperature and pressure, the density of H_2 is the minimum.

(B) When the weight is the same, the mole number of H_2 is the maximum.

(C) When the molar number is equal, NH_3 contains the largest number of atoms.

(D) At the same temperature, pressure, and volume, the weight of O_2 is the maximum.

(E) At the same temperature, volume, and weight, the pressure of H_2 is the maximum.

設有四種氣體：H_2、CH_4、O_2、NH_3。下列相關敘述哪些正確？（原子量：C＝12、N＝14、O＝16）

(A) 同溫同壓時，以 H_2 的密度最小。

(B) 等重時，以 H_2 的莫耳數最大。

(C) 等莫耳數時，NH_3 所含的原子數最多。

(D) 同溫同壓同體積時，以 O_2 的重量最大。

(E) 同溫同體積同重量時，以 H_2 的壓力最大。

（南一版 110 上課本（選修化學 I）第二章 習題 多選題第 5 題）

Teacher: Step one, calculate the molecular weight of the four gases.

Student: The molecular weight of H_2 is 2. CH_4 is 16. O_2 is 32. NH_3 is 17.

Teacher: Yes. Option A asks for density, so we should use PM=dRT. At the same temperature and pressure, what is the relationship between molecular weight and density?

Student: Molecular weight is proportional to density, so the density of H_2 is minimal at the same temperature and pressure.

Teacher: Excellent. What is the relationship between mole number and molecular weight at the same weight?

Student: The mole number is inversely proportional to molecular weight, so the mole number of H_2 is the largest at the same weight.

Teacher: Very good. When the mole number is the same, which gas contains the largest number of atoms at the same molar number?

Student: CH_4, because CH_4 contains 5 atoms.

Teacher: That's correct. Next, the volume is mentioned in options D and E, so we should use PV=nRT to find the answer, while n=W/M. At the same temperature, pressure, and volume, the mole number is also the same. What is the relationship between weight and molecular weight?

Student: Weight is proportional to molecular weight, so the weight of O_2 is the largest.

Teacher: Very smart. What is the relation between molecular weight and pressure at the same temperature, volume, and weight?

Student: Molecular weight and pressure are inversely proportional to pressure, so the pressure of H_2 is the largest.

Teacher: Very good, so what are the correct options for this question?

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

老師： 第一步先算出四種氣體的分子量。

學生： H_2 是 2，CH_4 是 16，O_2 是 32，NH_3 是 17。

老師： 沒錯，A 選項問密度，所以用 PM=dRT。同溫同壓時，分子量和密度關係為何？

學生： 分子量和密度成正比，所以同溫同壓時 H_2 密度最小。

老師： 很棒，相同重量時，莫耳數和分子量關係為何？

學生： 莫耳數和分子量成反比，所以相同重量時 H_2 莫耳數最多。

老師： 非常棒，相同莫耳數時，哪一種氣體所含的原子數最多呢？

學生： CH_4，因為 CH_4 有 5 個原子。

老師： 沒錯，接下來 D 和 E 選項提到體積，所以要用 PV=nRT 判斷，而 n=W/M。同溫同壓同體積時，代表莫耳數也相同，重量和分子量的關係為何？

學生： 重量和分子量成正比，所以 O_2 的重量最大。

老師： 很聰明，那同溫同體積同重量時，分子量和壓力的關係為何？

學生： 分子量和壓力成反比，所以 H_2 的壓力最大。

老師： 非常好，此題的正確選項是甚麼？

學生： (A) (B) (D) (E)。

例題二

說明：學生能了解理想氣體分子和真實氣體分子之間的差異。

Students can understand the differences between ideal gas molecules and real gas molecules.

Which of the following statements about real gas and ideal gas is incorrect?

(A) The molar volume of a real gas varies with the type of gas.

(B) The real gas molecule itself occupies volume and has mass, but the ideal gas molecule itself doesn't occupy volume and has no mass.

(C) At the standard temperature and pressure, the greater the attractive force between real gas molecules, the smaller the mole volume.

(D) Under high temperature and pressure, the real gas behavior is more consistent with the ideal gas.

(E) At normal temperature and pressure, the behavior of blunt gas (such as He and Ne) is close to ideal gas.

下列有關真實氣體和理想氣體的敘述，何者不正確？

(A) 真實氣體的莫耳體積，會隨氣體種類不同而異。

(B) 真實氣體分子本身佔有體積，具有質量；但是理想氣體分子本身不佔有體積，不具有質量。

(C) 標準溫壓下，若真實氣體分子間引力越大者，莫耳體積越小。

(D) 高溫、高壓條件下，真實氣體行為較能符合理想氣體。

(E) 常溫常壓下，鈍氣（如 He 與 Ne）接近理想氣體行為。

Teacher: What is the difference between ideal gas molecules and real gas molecules?

Student: The real gas molecule itself occupies volume and there is attraction between particles, but the ideal gas molecule itself does not occupy volume and there is no attraction between particles.

Teacher: Yes. The molar volume of real gas will vary with different types of gas. Do you remember which gas will be more consistent with the ideal gas?

Student: Noble gas, because it is a monatomic gas.

Teacher: Great. What if it's a polyatomic gas?

Student: This will be because the greater the intermolecular attraction force, the smaller the volume.

Teacher: Great job. Under which conditions will the real gas be more consistent with the ideal gas?

Student: At high temperature and low pressure.

Teacher: Very good, so what is the correct option for this question?

Student: (D).

老師： 理想氣體分子和真實氣體分子之間的差異為何？

學生： 真實氣體分子本身佔有體積，粒子間具有吸引力；但是理想氣體分子本身不佔有體積，粒子間無吸引力。

老師： 沒錯，而且真實氣體的莫耳體積會隨氣體種類不同而異，還記得哪種氣體會比較符合理想氣體嗎。

學生： 鈍氣，因為是單原子氣體。

老師： 很棒，那如果是多原子氣體呢？

學生： 會因為分子間引力越大者，體積越小。

老師： 非常棒，那在哪種條件下真實氣體會更符合理想氣體呢？

學生： 高溫低壓時。

老師： 那此題正確答案為何？

學生： (D)。

2-4 氣體分壓
Gas Partial Pressure

■ 前言 Introduction

在此小節中運用上一小節學過的理想氣體方程式，進而帶學生認識道耳頓的分壓定律，接著深入探討混合氣體之間各氣體分壓定律。

語言教學的部分，在教授氣體分壓定律時，可以運用上一小節所學的「推導」片語來幫助學生更清楚地理解式子之間的關係。在練習題和學生討論中，鼓勵學生多使用相關片語來表達所涉及的定律和解題原理。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
saturated vapor pressure	飽和蒸氣壓	gas collection by water displacement	排水集氣法
partial pressure	分壓	atmospheric pressure	大氣壓力
Dalton's partial pressure law	道耳頓分壓定律	cock	活栓
Gas collecting bottle	集氣瓶	correction	校正
gas collection by upward delivery	向上排氣法	gas collection by downward delivery	向下排氣法
total pressure	總壓		

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

❶ _____, that is _____.

例句：In a uniformly mixed gas system, the measured pressure is called the total pressure. The pressure value provided by each part of the gas is called the partial pressure, **that is**, the pressure when (of) each component of the gas occupies the container alone.
在一均勻混合的氣體系中，測得的壓力稱為總壓，而各部分氣體所提供的壓力值稱為分壓，即各成分氣體單獨占有該容器時的壓力。

❷ _____be equal to _____.

例句：In a system of nonreactive gases, the total pressure of the system **is equal to** the sum of the individual partial pressures.
在互不反應的氣體系統中，系統的總壓等於個別分壓之和。

❸ According to _____, _____.

例句：**According to** Dalton's partial pressure law, the total pressure is equal to the sum of the individual partial pressures.
根據道耳頓分壓定律可知總壓等於個別分壓之和。

❹ _____ be soluble in _____.

例句：It is necessary to collect gas that **is** not easily **soluble in** water, gas collection by water displacement is suitable.
若要收集不易溶於水的氣體，則適合用排水集氣法。

■ 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 this lesson, students should be able to know:

學生能學會道耳頓分壓定律的計算。

Students can learn to calculate Dalton's Law of Partial Pressures.

❧ 例題講解 ☙

例題一

說明：學生能活用理想氣體方程式和道耳頓分壓定律的計算。

Students can use the ideal gas equation and Dalton's law of partial pressure calculations.

Student Lin wanted to explore the purity of a bottle of old potassium chlorate ($KClO_3$) reagent in the laboratory. From what he learned in class, he learned that potassium chlorate can be completely decomposed at high temperatures to produce potassium chloride and oxygen, so he took 1.50 g of the potassium chlorate sample and put it in the test tube. It is heated and decomposed, and oxygen is collected by the method of water drainage and gas collection until no more oxygen is produced, and a total of 250 mL of oxygen is collected. During the experiment, the temperature of the water is 32°C and the atmospheric pressure is 736 mmHg. Based on the above experimental data, try to answer the following questions. (It is known that the saturated vapor pressure of water at 32°C is 36 mmHg, and the solubility of oxygen is extremely small and negligible)

How many moles of oxygen were collected in this experiment?

(A) 1.6×10^{-3}

(B) 4.1×10^{-3}

(C) 9.2×10^{-3}

(D) 8.8×10^{-2}

(E) 7.3×10^{-2}

林同學欲分析實驗室內一瓶陳舊氯酸鉀（$KClO_3$）的純度，由上課所學得知：氯酸鉀在高溫下可完全分解產生氯化鉀和氧氣，於是取此氯酸鉀試樣 1.50 g，將其加熱分解，並用排水集氣法收集氧氣，直到不再有氧氣產生，共收集 250 mL 的氧氣。若實驗時，水的溫度為 32℃、大氣壓力為 736 mmHg。依上述實驗數據，試回答下列問題。（已知 32℃時水的飽和蒸氣壓為 36 mmHg，且氧氣的溶解度極小，可忽略不計）

此實驗共收集多少莫耳的氧氣？理想氣體常數 R＝0.0820 L atm K－1 mol －1

(A) 1.6×10^{-3}

(B) 4.1×10^{-3}

(C) 9.2×10^{-3}

(D) 8.8×10^{-2}

(E) 7.3×10^{-2}

（107 指考 第 18 題）

Teacher: The question requires calculating the mole number of oxygen. Although we can't directly get from the question, what can we get from this information?

Student: Partial pressure of oxygen.

Teacher: Yes. According to what law do we know the partial pressure of oxygen?

Student: According to Dalton's partial pressure law, total pressure = partial pressure + saturated vapor pressure of water. Therefore, 736=oxygen partial pressure+36, and we can know that the partial pressure of oxygen is 700mmHg.

Teacher: Good job. After knowing the partial pressure of oxygen, what formula can we use to calculate the number of moles of oxygen?

Student: The ideal gas equation.

Teacher: That's correct, so how to formulate according to the equation PV=nRT?

Student: (700/760) * 0.25=n * 0.0821 * (32+273), so n = 9.2 * 10^{-3} moles.

Teacher: Yes, so the answer is (C).

老師：題目所求為算出氧氣的莫耳數，雖然沒辦法由題目已知的資訊直接求得，不過我們可以先從題目求出什麼？

學生：氧氣的分壓。

老師：沒錯，我們是根據什麼定律來得知氧氣的分壓？

學生：根據道耳頓分壓定律可知總壓＝氧氣分壓＋水的飽和蒸氣壓。因此 736=氧氣分壓+36，可得氧氣分壓為 700mmHg。

老師： 很好，求得氧氣分壓後我們能利用前面所學的什麼公式來算出氧氣的莫耳數？
學生： 理想氣體方程式。
老師： 沒錯，因此根據方程式 PV=nRT 該如何列式。
學生： (700/760) * 0.25=n * 0.0821* (32+273)，因此 n＝9.2 * 10^{-3} 莫耳。
老師： 沒錯，故答案選(C)。

例題二

說明：學生能利用道耳頓分壓定律得知容器中混合氣體的總壓力等與各成分氣體壓力的總和。

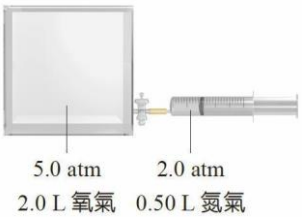
Students can use Dalton's law of partial pressure to know that the total pressure of the mixed gas in the container is equal to the sum of the pressures of the individual gases.

At 27 °C, fill the syringe with nitrogen gas of 2.0 atm and volume of 0.50 L, and another container filled with oxygen of 5.0 atm and volume of 2.0 L (as shown in the figure on the right). After opening the cock, fill the syringe with nitrogen gas completely. Into the container, assuming that the volume of the thin tube connected in the middle is ignored, what is the final total pressure?

(A) 5.5 (atm)
(B) 6.6 (atm)
(C) 7.7 (atm)
(D) 8.8(atm)

27 °C 時，以針筒裝入 2.0 atm、體積 0.50 L 氮氣，另外容器中裝有 5.0 atm、體積 2.0 L 的氧氣（如右圖），將活栓打開後，將針筒內的氮氣完全灌入容器中，假設中間連接細管體積不計，則最後總壓力為多少？

(A) 5.5 (atm)
(B) 6.6 (atm)
(C) 7.7 (atm)
(D) 8.8(atm)



（翰林版 110 上課本（選修化學 I）第二章 第 28 頁 素養範例 2-10 題）

Teacher: From the description in the question, what law can we use to find the total pressure?

Student: Dalton's law of partial pressure.

Teacher: Yes, so we can get it by adding the partial pressures of nitrogen and oxygen. How can we get the partial pressure of nitrogen?

Student: According to Boyle's law $P_1V_1=P_2V_2$, we can know the relationship between the pressure and the volume before and after opening the cock to calculate the nitrogen partial pressure. 2 * 0.5 = P2 * 2. We realized that the nitrogen partial pressure is 0.5 atm.

Teacher: Excellent. How can I get the partial pressure of oxygen?

Student: Because there are still two liters of gas after opening the cock, the partial pressure of oxygen remains unchanged at 5 atm.

Teacher: Wonderful, so how do we find the total pressure?

Student: 0.5 + 5.0 = 5.5 atm. The answer is (A).

老師： 由題目中的描述，我們為了求得總壓，因此可以利用什麼定律來求得？

學生： 道耳頓分壓定律。

老師： 沒錯，因此我們可以由氮氣及氧氣的分壓相加求得，那我們該如何求得氮氣的分壓？

學生： 根據波以耳定律 $P_1V_1=P_2V_2$ ，可以知道打開活栓之前後壓力與體積的關係求出氮氣分壓，2 * 0.5＝P2 * 2，得到氮氣分壓為 0.5atm。

老師： 很好，那氧氣的分壓該如何求得？

學生： 因為打開活栓後仍為兩公升的氣體，因此氧氣分壓不變一樣為 5atm。

老師： 很好，因此總壓如何求出？

學生： 0.5 + 5.0 = 5.5 atm，答案選（A）。

★主題三 液態與溶液★
Liquid and Solution

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■ 前言 Introduction

本章首先藉由學生在國中已學過的水的三相變化時吸熱和放熱的現象，介紹熱焓、蒸氣壓及相對溼度，接著介紹拉午耳定律，探討不同溶質及溶劑對飽和蒸氣壓的影響，最後探討溶液的蒸氣壓下降、沸點上升、凝固點下降、滲透壓等各項依數性質及應用。

3-1 水的性質
Properties of Water

■ 前言 Introduction

本小節介紹了水的三相變化及蒸氣壓。在國中階段學生已習得水溶液中的變化，教師應先從前導觀念複習，接著再進行延伸帶入主題。此小節在計算熱焓時，建議教師為學生複習熱量的計算公式。

語言部分，教師提供各種熱含量變化的單字用法，並以提供句型讓學生說出水的三相變化及蒸氣壓的意義，教師可以在學生完成單句後給予回饋。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
heat of melting	熔化熱	melting point	熔點
freezing heat	凝固熱	molar heat of fusion	莫耳熔化熱
heat of vaporization	汽化熱	molar heat of vaporization	莫耳汽化熱
heat of condensation	凝結熱	boiling point	沸點
heat of sublimation	昇華熱	vaporization	汽化
relative humidity	相對溼度	apparent temperature	體感溫度
evaporation	蒸發	boiling	沸騰
heating curve	加熱曲線		

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

❶ When _____, _____.

例句：**When** a substance vaporizes from a liquid to a gas, the change in its heat content is called the heat of vaporization, denoted by ΔH°_{vap}.
物質由液態汽化成氣態時，其熱含量變化稱為汽化熱，以 ΔH°_{vap}表示。

❷ _____ is called _____.

例句：A mole of water molecules changes from solid to liquid, and the energy absorbed **is called** the molar heat of fusion.
1 莫耳水分子由固態轉變成液態，其所吸收的能量值稱莫耳熔化熱。

❸ _____ will _____ accordingly.

例句：When the temperature rises, the saturated vapor pressure **will** increase **accordingly.**
當溫度愈高時，飽和蒸氣壓會跟著上升。

❹ _____ can be defined as _____.

例句：Relative humidity **can be defined as** the percentage ratio between the partial pressure of water vapor in the air and the saturated vapor pressure of water at this temperature.
相對溼度可定義為空氣中水蒸氣的分壓與該溫度下水的飽和蒸氣壓的百分比值。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學完本單元後，學生應學會以下觀念：

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

學生能學會物質狀態能量的變化及蒸氣壓。

Students learn about energy changes in states of matter and vapor pressure.

❧ 例題講解 ☙

例題一

說明：學生能了解不同物質有不同的飽和蒸氣壓。

Students learn that different substances have different saturation vapor pressures.

The saturated vapor pressure (mmHg) of the four liquids A, B, C, and D are shown in the table below:

The order of magnitude of normal boiling point?

(A) B＞A＞C＞D

(B) B > C > A > D

(C) C > A > B > D

(D) D > A > B > C

temperature（°C）Liquid saturated vapor pressure（mmHg）	25	50	75	100
A	24	93	289	760
B	32	87	201	644
C	57	212	631	1795
D	103	317	845	1476

四種液體 A、B、C、D 的飽和蒸氣壓（mmHg）如下表所示：

正常沸點的大小順序？

(A) B＞A＞C＞D

(B) B > C > A > D

(C) C > A > B > D

(D) D > A > B > C

溫度（°C）液體的飽和蒸氣壓（mmHg）	25	50	75	100
A	24	93	289	760
B	32	87	201	644
C	57	212	631	1795
D	103	317	845	1476

（來源：翰林版 110 上課本（選修化學 I）第三章 P22 練習 3-7)

Teacher: Before solving the question, can you tell me what is the definition of normal boiling point that we learned in class?

Student: As mentioned in the textbook, when the temperature rises, the saturated vapor pressure of various substances will increase accordingly. When the saturated vapor pressure increases to 760 mmHg, it will just balance with the atmospheric pressure, and the substance will start to boil. The temperature measured at this time is called the normal boiling point.

Teacher: Excellent. We can know from the definition that if a substance reaches a saturated vapor pressure of 760mmHg at a lower temperature, it has a lower normal boiling point and the opposite is true. Now, from the perspective of the four substances A, B, C, and D, how should we put them in order, from the high one to the low one, based on the normal boiling point?

Student: We should find the temperature corresponding to the saturated vapor pressure of the four substances at 760 mmHg.

Teacher: That's right, what are the temperatures corresponding to the saturated vapor pressure of the four substances A, B, C, and D at 760 mmHg?

Student: A is 100˚C; B is over 100˚C; C is between 75˚C~100˚C; D is between 50˚C~75˚C.

Teacher: Great. We can then rank the number of the normal boiling point, and the answer is (A) B＞A＞C＞D.

老師： 在解出這題之前，想先問問各位同學還記不記得我們在課堂中學到正常沸點的定義是什麼？

學生： 課本中提到，當溫度上升時，各種物質的飽和蒸氣壓會跟著增加，當飽和蒸氣壓增加到 760mmHg 時，剛好會與大氣壓力平衡，物質便會開始沸騰，此時測量到的溫度就稱為正常沸點。

老師： 很好。因此我們可以知道若物質在溫度較低時便可達到 760mmHg 的飽和蒸氣壓的話，則我們可以說此物質有較低的正常沸點；若物質在溫度較高時才可達到 760mmHg 的飽和蒸氣壓的話，則我們可以說此物質有較高的正常沸點。因此由 A、B、C、D 四種物質來看我們該如何排序正常沸點的大小？

學生： 找出四種物質的飽和蒸氣壓在 760mmHg 下所對應的溫度。

老師： 沒錯，那 A、B、C、D 四種物質分別在 760mmHg 的對應溫度為何？

學生： A 為 100°C、B 超過 100°C、C 介在 75°C~100°C、D 介在 50°C~75°C

老師： 很好，所以我們即可排列出正常沸點的大小，因此答案選(A) B＞A＞C＞D。

例題二

說明：學生能了解液體的性質。

Students can understand the properties of liquids.

Which statements about the properties of liquids are correct?

(A) At the same temperature, the higher the saturated vapor pressure of the liquid, the lower the boiling point.

(B) At the same temperature, the higher the saturated vapor pressure of the liquid, the smaller the intermolecular force.

(C) Boiling begins when the rate of evaporation of the liquid equals the rate of condensation of the vapor.

(D) Boiling begins when the rate of evaporation of the liquid is greater than the rate of condensation of the vapor.

(E) Under constant pressure, the higher the boiling point of the liquid, the greater the intermolecular force.

有關液體性質的敘述，正確的有哪些？

(A) 同溫時，液體的飽和蒸氣壓越大者，沸點越低。

(B) 同溫下，液體的飽和蒸氣壓越大者，分子間作用力越小。

(C) 當液體的蒸發速率等於蒸汽的凝結速率時，則開始沸騰。

(D) 當液體的蒸發速率大於蒸汽的凝結速率時，則開始沸騰。

(E) 定壓下，液體的沸點越高，則分子間作用力越大。

（來源：龍騰版 110 上課本（選修化學 I）第三章 第 148 頁 習題 3-1-1）

Teacher: How would we describe such a state, in which the number of evaporated and condensed particles per unit of time is the same at a constant temperature? We have learned this in class!

Student: The evaporation rate is equal to the condensation rate.

Teacher: Very good. We also call such a process to be “achieving a dynamic balance.” Now when will a substance start to boil?

Student: When the temperature rises, the saturated vapor pressure of various substances will increase accordingly. When the saturated vapor pressure increases to 760mmHg, it will just balance with the atmospheric pressure, and the substance will start to boil.

Teacher: Yes, so which two of the following options are incorrect?

Student: (C) and (D).

Teacher: As we have learned, when substances are at the same temperature and with a higher saturated vapor pressure of the liquid, would the boiling point be higher or lower?

Student: Lower. The substance is at a temperature closer to its boiling point.

Teacher: At the same temperature, does the greater saturated vapor pressure of the liquid have greater intermolecular force, or the smaller one?

Student: The smaller, because substances with lower boiling points indicate that the force between particles is smaller.

Teacher: Yes, so options (A) and (B) are both correct. How about option (E)?

Student: It is correct, because under constant pressure, the higher the boiling point of the liquid, the greater the force between molecules.

老師： 我們在課堂中學過，在定溫下當單位時間內蒸發和凝結的粒子數相同時，我們會怎麼描述這樣的狀態？

學生： 蒸發速率＝凝結速率。

老師： 很好，我們也稱這樣的過程是達到一種動態平衡。而要讓物質開始沸騰和什麼有關？

學生： 當溫度上升時，各種物質的飽和蒸氣壓會跟著增加，當飽和蒸氣壓增加到760mmHg 時，剛好會與大氣壓力平衡，物質會開始沸騰。

老師： 沒錯，因此有哪兩個選項錯了？

學生： (C)、(D)

老師： 而我們知道物質在同溫時，液體的飽和蒸汽壓越大者沸點會越高還是越低？

學生： 越低，因為表示此物質離正常沸點更接近。

老師： 那同溫時，液體的飽和蒸汽壓越大者，分子間的作用力越大還越小呢？

學生： 越小，因為沸點低的物質表示粒子之間的作用力小。

老師： 沒錯，因此(A)、(B)選項皆正確。那(E)選項是否正確呢？

學生： 正確，因為定壓下，液體的沸點越高，表示分子間的作用力越大。

3-2 溶液的蒸氣壓與拉午耳定律
Vapor Pressure of Solution and Raoult's Law

■ 前言 Introduction

在本小節教師利用前一小節所學的蒸氣壓當作引導，介紹溶液的蒸氣壓與拉午耳定律，帶學生探討溫度和飽和蒸氣壓彼此之間的關係，並去了解不同溶質及溶劑對飽和蒸氣壓的影響。

教師在進行課程時，應妥善運用解釋分率之句型與片語，並讓學生以總結與歸納的句型表達對於定理及定律的理解。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
molar fraction	莫耳分率	dilute solution	稀薄溶液
colligative property	依數性質	Raoult's law	拉午耳定理
ideal solution	理想溶液	Henry's law	亨利定律
fractional distillation	分餾	solubility curve	溶解度曲線

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

❶ _____ be proportional to_____.

例句：At a constant temperature, when a non-volatile solute is added to a solvent to form a dilute solution, the vapor pressure of the solution will **be proportional to** the mole fraction of the solvent in the solution, which is called Raoult's law.

定溫下，將非揮發性溶質加入溶劑中形成稀薄溶液時，溶液的蒸氣壓會與溶劑在溶液中的莫耳分率成正比，稱為拉午耳定律。

❷ _____be equal to_____.

例句：When the solution contains nonvolatile and non-electrolyte solutes, the vapor pressure of the solution **is equal to** the product of the saturated vapor pressure of the pure solvent and the molar fraction of the solvent in the solution.

當溶液中含有非揮發性、非電解質溶質時，溶液的蒸氣壓等於純溶劑的飽和蒸氣壓與溶劑在溶液中的莫耳分率之乘積值。

❸ _____comply with _____.

例句：A solution that completely **complies with** Raoult's law is called an ideal solution

完全遵守拉午耳定律的溶液，我們稱之為理想溶液。

❹ At constant _____, _____.

例句：**At constant** temperature and pressure, when the number of molecules of carbon monoxide gas exchanged between the liquid phase and the gas phase is the same in a unit time in a closed container, it is called the solution equilibrium state.

定溫、定壓下，於密閉容器中，單位時間內一氧化碳氣體溶解在液相與逸出氣相之間的分子數相同時，稱為溶解平衡狀態。

■ 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:

學生能了解理想溶液與拉午耳定律及氣體的溶解度。

Students can understand the ideal solution and Raoult's law and gas solubility.

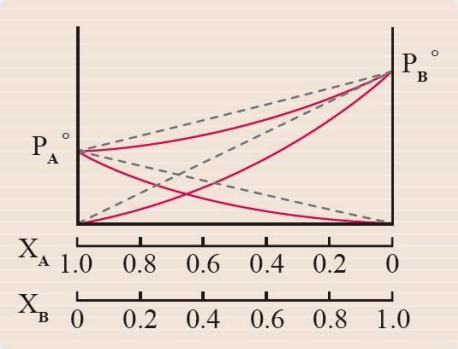
❧ 例題講解 ☙

例題一

說明：學生能了解理想溶液和非理想溶液的意義。

Students can understand the meaning of ideal and non-ideal solutions.

According to the figure on the right, the red line represents the vapor pressure curve of the solution measured after mixing A and B in various proportions, and the dotted line represents the ideal solution. Which of the following statements are correct?



(A) Intermolecular attraction increases after mixing.

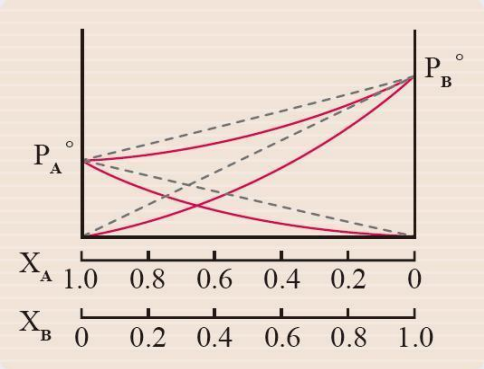
(B) A liquid has a lower boiling point.

(C) Take 10 mL each of A and B. After mixing the two liquids, the volume of the solution is less than 20 mL.

(D) The mixing process is an endothermic reaction.

(E) With Positive deviation from Raoult's law.

根據右圖，紅線表示 A、B 以各比例混合後測得的溶液蒸氣壓曲線，虛線表示理想溶液，則下列各項敘述哪些正確？



(A) 混合後分子間引力變大。

(B) A 液體的沸點較低。

(C) 各取 10 mL A、B 兩液體混合後，溶液體積小於 20 mL。

(D) 混合過程為吸熱反應。

(E) 對拉午耳定律呈現正偏差。

（翰林版 110 上課本（選修化學 I）第三章 P28 範例 3-9）

Teacher: As what we learned in class, if there is no change in the force before and after the solute and solvent are mixed, what law or principle does such a situation obey?

Student: Raoult's law is also known as the ideal solution.

Teacher: That's right. On the contrary, if the solute and the solvent form a strong force after mixing, the distance between the particles will be shortened. Will the volume of the solution turn out to increase or decrease?

Student: It will decrease.

Teacher: Yes, such a situation will be an exothermic reaction, causing the vapor pressure of the solution to drop. In this case, we call it a positive deviation, or a negative deviation.

Student: It is a negative deviation.

Teacher: That's right, and the picture in this question describes the negative deviation of the non-ideal solution. So we can judge from the graph which options are correct and which options are not?

Student: (A) and (C) are correct, while (B), (D), and (E) are not.

Teacher: That's right, how should we correct the mistakes in (B), (D), and (E)?

Student: (B) is changed to liquid A with a higher boiling point; (D) is an exothermic reaction; (E) is a negative deviation.

老師： 在課堂中我們學過，若是溶質和溶劑混合前後沒有作用力變化，我們可以稱這樣的情況遵守什麼定律？

學生： 拉午耳定律。也就是理想溶液。

老師： 沒錯，反之，若溶質和溶劑混合後彼此形成強作用力，則會拉近粒子之間彼此的距離，因此溶液體積會減少還是增加？

學生： 體積減少。

老師： 沒錯，這樣的情形會是一個放熱反應，讓溶液的蒸氣壓下降，這樣我們稱為正偏差還是負偏差？

學生： 負偏差。

老師： 沒錯，而此題的圖正是描述非理想溶液負偏差的情況。因此我們可以再從圖判斷出哪些選項正確哪些選項錯誤？

學生： (A)、(C)正確，(B)、(D)、(E)錯誤。

老師： 沒錯，那我們應該如何更正(B)、(D)、(E)的錯誤呢？

學生： (B)改為 A 液體的沸點較高，(D)為放熱反應，(E)則為負偏差。

例題二

說明：學生能了解氣體的溶解度與亨利定律的意義。

Students can understand the solubility of gas and the significance of Henry's Law.

At 25˚C, the pressure of carbon dioxide gas above sea level is 0.0025 atmospheres. If it is known that the solubility of carbon dioxide gas is 0.0040M at this temperature and pressure, answer the following questions based on the above:

(1) From the formula of Henry's law, what is the size of Henry's law constant k_H in M/atm? **k_H=1.6M/atm**

(2) If the gas pressure of carbon dioxide becomes 0.0050 atmospheres, how many grams of carbon dioxide can be dissolved in 1 liter of water? **0.35g**

25˚C 時，海平面上方的二氧化碳氣體壓力為 0.0025 大氣壓，若已知在此溫度與壓力下，二氧化碳氣體的溶解度為 0.0040M，根據上述回答下列問題則

(1) 由亨利定律式求亨利定律常數 k_H 大小為多少 M/atm? **k_H =1.6M/atm**

(2) 若二氧化碳的氣體壓力變為 0.0050 大氣壓，則 1 公升的水中可溶入幾克的二氧化碳？ **0.35g**

（來源：龍騰版 110 上課本（選修化學 I）第三章 第 124 頁 例 3-7）

Teacher: Based on Henry's law, we know that at a constant temperature, the solubility of an insoluble gas solute in a solvent is proportional to the partial pressure of the gas on the liquid surface. To generate a relational, we need a constant, which will be Henry's constant, and in this way, it can be written as the formula $S_g = k_H * P_g$. Now how do we find the answer to the first question?

Student: Because $S_g = k_H * P_g$, $0.0040M = k_H * 0.0025$ atm. Therefore, $k_H = 1.6M/atm$.

Teacher: Very good, we now have Henry's constant, so as our gas pressure changes, our solubility will also change. The question is if the gas pressure of carbon dioxide is changed to 0.0050 atm, how many grams of carbon dioxide can be dissolved in 1 liter of water?

Student: By bringing $k_H = 1.6M/atm$ into Henry's Law formula $S_g = k_H * P_g$, and assuming that the solubility of carbon dioxide is x M, we can get $x=1.6M/atm*0.0050atm=0.0080M$.

Teacher: That's right, how do we come up with the number after we have the concentration?

Student: Weight/molar mass is equal to mole number, and mole number is equal to volume mole concentration multiplied by solution volume. As a result, the weight of carbon dioxide is 0.0080M*1L*44 g/mol, which is 0.35g.

老師： 我們學過亨利定律的定義就是在定溫下，難溶的氣體溶質在溶劑裏面的溶解度和液面上此氣體的分壓會成正比，因此為了寫成一個關係式，我們需要一個常數，也就是亨利常數，如此一來就能寫成公式 Sg=KH*Pg，所以我們該如何求出第一小題的答案？

學生： 因為 $S_g = k_H * P_g$，$0.0040M = k_H * 0.0025$ atm，所以 $k_H = 1.6M/atm$。

老師： 很好，我們現在有了亨利常數，所以隨著我們氣體壓力的改變，我們的溶解度也會跟著改變，因此今天題目若是讓二氧化碳的氣體壓力變為 0.0050 大氣壓，則 1 公升的水中可溶入幾克的二氧化碳？

學生： 將 $k_H = 1.6M/atm$ 帶入亨利定律的公式 $S_g = k_H * P_g$，並假設二氧化碳的溶解度為 x M，則 $x=1.6M/atm*0.0050atm=0.0080M$。

老師： 沒錯，那我們有了濃度之後該如何算出克數呢？

學生： 重量/莫耳質量＝莫耳數，而莫耳數＝體積莫耳濃度*溶液體積，所以二氧化碳的重量＝0.0080M*1L*44g/mol=0.35g

3-3 溶液的性質
Properties of the Solution

■ 前言 Introduction

本小節探討電解質與非電解質的非揮發性溶液的蒸汽壓改變，引起沸點和凝固點的變化，以及認識依數性質的應用，包括沸點上升，凝固點下降，滲透壓，並以日常生活實例說明滲透與逆滲透的現象。

本節語言學習重點在於以相關詞彙表達在不同的條件下（under the condition of…）溶液不同的性質。其餘句型在於幫助學生理解不同溶液性質的變化與特性。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
vapor pressure	蒸氣壓	freezing point	凝固點
pure solvent	純溶劑	nonvolatile	非揮發性
antifreeze	抗凍劑	Van't Hoff factor	凡特何夫因子
osmotic pressure	滲透壓	semipermeable membrane	半透膜
osmosis	滲透作用	isotonic solution	等張溶液
hypertonic solution	高張溶液	hypotonic solution	低張溶液
boiling-point elevation	沸點上升	freezing-point depression	凝固點下降

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

❶ _____nothing but _____.

例句：$\Delta T_b = K_b \times C_m$ applies **nothing but** dilute solutions formed by non-volatile and non-electrolyte solutes.

$\Delta T_b = K_b \times C_m$ 僅適用於非揮發性、非電解質溶質所形成的稀薄溶液。

❷ Under the condition of_____, _____.

例句：**Under the condition of** quantitative solvent, the more moles of solute, the higher the degree of boiling point elevation.

在定量溶劑的條件下，溶質莫耳數愈多，沸點上升度數愈高。

❸ adding _____ in _____.

例句：**Adding** ethylene glycol as an antifreeze **in** the water tank is an application of freezing point depression in life.

在水箱中加入乙二醇做為抗凍劑是凝固點下降在生活中的應用。

❹ _____ be related to _____.

例句：According to the colligative property, whether the solute particles are in molecular or ionic ion state, the amount of vapor pressure drop, the degree of boiling-point elevation and the degree of freezing-point depression of the solution **are** all **related to** the number of solute particles.

根據依數性質，無論溶質粒子為分子或離子狀態，蒸氣壓下降量、溶液的沸點上升度數與凝固點下降度數皆與溶質粒子個數有關。

❺ _____ depend on _____.

例句：The property of the solution **depends** only **on** the number of solute particles, but has nothing to do with the nature of the solute, which is called the colligative property.

溶液的性質只取決於溶質粒子的數量，而與溶質的本質無關，稱為依數性質。

■ 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:

學生能了解溶液依數性質的應用，包括溶液的蒸氣壓下降、沸點上升、凝固點下降及滲透壓。

Students can understand the application of solution colligative properties, including vapor pressure drop, boiling-point elevation, freezing-point depression, and osmotic pressure.

❧ 例題講解 ☙

例題一

說明：學生能藉由蒸汽壓與溫度的關係判斷沸點高低及溶液濃度。

Students can use the relationship between vapor pressure and temperature to determine the boiling point and solution concentration.

It is known that the relationship between vapor pressure and temperature of non-electrolyte solutions a and b composed of pure solvent c is shown in the figure below (K_b of pure solvent c = 1°C m^{-1}). Which of the following statements is correct?

(A) The concentration of solution A is 3 M.

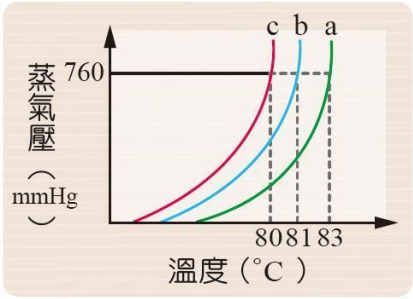
(B) The volume mol concentration of solution B is 1 M.

(C) The solute molecular weight of solution A is 30.

(D) Boiling point: a ＜ b ＜ c.

(E) To make solution b boil at 80 ° C, the liquid level pressure should be less than 760 mmHg.

已知由純溶劑 c 和非電解質 a 及 b 所組成的溶液，其蒸氣壓對溫度關係圖如下圖（純溶劑 c 的 $K_b = 1\ °C\ m^{-1}$），則下列敘述何者正確？



(A) a 溶液的濃度為 3 M。

(B) b 溶液的體積莫耳濃度為 1 M。

(C) a 溶液之溶質分子量為 30。

(D) 沸點高低：a＜b＜c。

(E) 欲使 b 溶液在 80 °C 沸騰，則液面壓力應小於 760 mmHg。

（來源：翰林版 選修化學 I 課本 第三章 習題 基本題第 16 題）

Teacher: The subject of this question is to understand the relationship between the vapor pressure of a non-electrolyte solution and the degree of boiling-point elevation. Knowing the K_b of the pure solvent c from the description, and knowing the ΔT of the solution a and b through the figure, what formula do you relate?

Student: $\Delta T = K_b \times C_m$.

Teacher: That's right, then after we bring the ΔT of the solutions a and b and pure solvent c, and the K_b of pure solvent c mentioned in the description into the formula, we can find out what is C_m, can we?

Student: Yes. The C_m of solution a is 3m and the C_m of solution b is 1m.

Teacher: Great, note here that the weight molar concentration unit is m, not the volume molar concentration M. Can we find the molecular weight of the solute in solution a?

Student: Hmm... I cannot find it.

Teacher: That's fine, this question does not give the molecular weight of the solvent, so the molecular weight of the solute in solution cannot be found. Next, look at the picture to judge what is the boiling point under the same vapor pressure?

Student: Taking 760 mmHg for example, a is 83°C, b is 81°C, and c is 80°C, so the boiling point is a>b>c.

Teacher: Great, option (E) asks if solution b boils at 80 °C, is the vapor pressure higher or lower than that of 760 mmHg? Let's look at the vapor pressure corresponding to solution b at the boiling point of 80 °C in the figure.

Student: Lower!
Teacher: That's right, so what is the correct option?
Student: (E) is correct.

老師： 這題，目的是了解非電解質溶液蒸汽壓與沸點上升度數的關係。從敘述知道純溶劑 c 的 K_b，以及透過圖可以得知溶液 a、b 的ΔT，你們會聯想到什麼公式？
學生： $\Delta T = K_b \times C_m$。
老師： 沒錯，那我們把溶液 a 和 b 與純溶劑 c 的ΔT，以及題目告知的純溶劑 c 的 K_b 帶入公式，求出 C_m 為多少？
學生： 溶液 a 的 C_m 為 3m，溶液 b 的 C_m 為 1m。
老師： 非常棒，這邊要注意重量莫耳濃度單位是 m，不是體積莫耳濃度 M。那我們可以求出 a 溶液溶質的分子量嗎？
學生： 嗯.....好像求不出來耶。
老師： 沒錯，這題沒有給溶劑的分子量，所以求不出 a 溶液溶質的分子量。接下來看圖判斷相同蒸氣壓下沸點的高低為何？
學生： 以 760 mmHg 為例，a 為 83°C，b 為 81°C，c 為 80 °C，因此沸點是 a>b>c。
老師： 很棒，(E)選項問如果 b 溶液在 80 °C 沸騰，蒸氣壓比 760 mmHg 高還低呢？我們看圖中沸點 80 °C 時的溶液 b 對應的蒸氣壓。
學生： 低於 760 mmHg。
老師： 沒錯，所以正確的選項為何？
學生： (E)選項是正確的。

例題二

說明：學生能利用濃度和滲透壓判斷水的滲透方向。
Students can judge the direction of water infiltration through concentration and osmotic pressure.

In mammalian nerve cell membranes, the concentration of sodium ions is about one-tenth of that outside the cell membrane. If only the above conditions are considered, which of the following statements is correct?

(A) Water will osmose from inside of the cell membrane.
(B) Sodium ions will osmose from the inside of the cell membrane.
(C) Water will osmose from outside of the cell membrane.
(D) Sodium ions will osmose from outside of the cell membrane.
(E) Water molecules cannot penetrate the cell membrane.

哺乳類神經細胞膜內，鈉離子濃度約為細胞膜外的十分之一，若僅考慮上述條件，則下列敘述何者正確？

(A) 水會由細胞膜內向外滲透。
(B) 鈉離子會由細胞膜內向外滲透。
(C) 水會由細胞膜外向內滲透。
(D) 鈉離子會由細胞膜外向內滲透。
(E) 水分子無法穿過細胞膜進行滲透。

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Teacher: From the description, can you tell whether the concentration of sodium ions inside the cell is higher than that outside the cell?
Student: Yes. The concentration of sodium ions in the cells is lower.
Teacher: That's right, can sodium ions and water pass through cell membranes?
Student: Sodium ions cannot pass through the cell membrane, but water can pass through the cell membrane.
Teacher: Great, so we are sure that (B), (D), and (E) are incorrect. Now we have to judge which way the water will seep. Is the intracellular osmotic pressure higher or lower?
Student: The intracellular osmotic pressure is lower because of the lower intracellular concentration.

Teacher: That's right, and since water moves from low osmotic pressure to high osmotic pressure, how does water permeate?
Student: Water will permeate from the cell membrane to the outside, so the answer is (A)
Teacher: Good job.

老師： 依據題目敘述可以知道細胞內的鈉離子濃度比細胞外高還是低呢？
學生： 細胞內的鈉離子濃度較低。
老師： 沒錯，鈉離子和水會通過細胞膜嗎？
學生： 鈉離子不會通過細胞模，但是水可以通過。
老師： 非常棒，所以我們可以確定(B)(D)(E)選項是錯誤的，再來我們要判斷水會往哪邊滲透，請問細胞內滲透壓較高還是低？
學生： 細胞內滲透壓較低，因為細胞內濃度低。
老師： 沒錯，因為水會由滲透壓低往滲透壓高移動，所以水會如何滲透？
學生： 水會由細胞膜內向外滲透，所以答案選(A)。
老師： 你們真棒。

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

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