馬來西亞留台成功大學校友會

主　辦

2024 年

第三十九屆成大數理比賽

考生指示：

（一）解答所有問題。

（二）將正確答案在答案紙上的圓圈內"塗黑"，每題只准給一個答案。

（三）正確的答案得三分，錯誤的答案扣一分，不做答的零分。

INSTRUCTIONS TO CANDIDATES

1. **Attempt all questions.**

2. **Pick the correct answer and make a mark "●" in the circle provided in the answer sheet. Only one answer is allowed for each question.**

3. **Three marks for a correct answer, one mark will be deducted for each wrong answer. No mark will be given to each question not attempted.**

2024 年第三十九屆成大數理比賽 – 化學
39th NCKU Science and Mathematics Competition 2024 – Chemistry

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.0											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.0	17 Cl 35.5	18 Ar 40.0
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 64.0	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 80.0	36 Kr 83.8

1. When aromatic compound **A** with the molecular formula C_8H_{10} reacts with bromine water under appropriate catalysis, it forms compound **B**, which has two structures with the molecular formula C_8H_9Br. What is the molecular structure of compound **A**?

芳香族化合物 A 的分子式為 C_8H_{10}。此化合物在適當催化劑的催化下，與溴水反應可得化合物 B，化合物 B 有 2 種結構，其分子式為 C_8H_9Br。試問化合物 A 的分子結構圖為何？
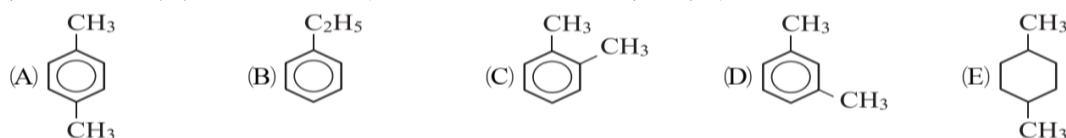
2. Which of the following statements about benzene is **correct**?
以下有關苯的敘述，哪個**正確**？
(A) Its carbon atoms are sp^2 hybridized, and the bond angle between atoms in the molecule is 109°.
   其碳為 sp^2 混成軌域，分子中各原子間角度為 109°
(B) Benzene is chemically reactive and undergoes addition reactions with hydrogen at room temperature and pressure.
   苯化性活潑，常溫、常壓下與氫進行加成反應
(C) It can react with a mixture of concentrated sulfuric acid and concentrated nitric acid to produce nitrobenzene.
   能和濃硫酸與濃硝酸的混合酸反應產生硝基苯
(D) One molecule of benzene burns in air to produce 6 molecules of CO_2 and 6 molecules of H_2O.
   1個苯分子在空氣中燃燒，會產生 6個 CO_2 分子與 6個 H_2O 分子
(E) Under ultraviolet radiation, benzene can react with chlorine to produce chlorobenzene (C_6H_5Cl).
   在紫外光照射下，可和氯氣反應產生氯苯 (C_6H_5Cl)

3. Which of the following statements about the molecular structure of ethyl acetate ($CH_3COOCH_2CH_3$) is **correct**?
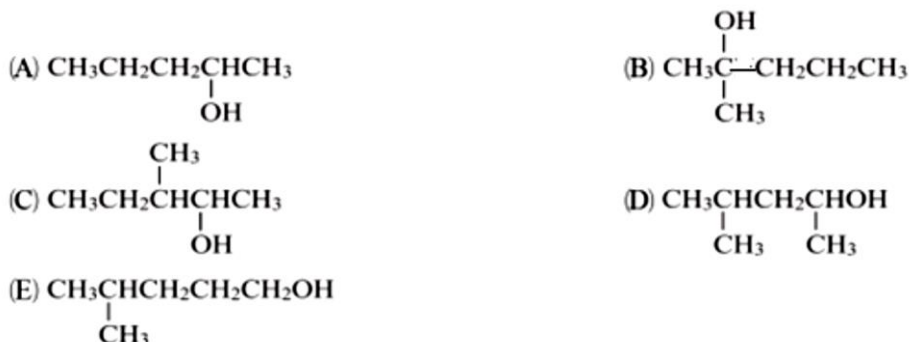下列有關化合物乙酸乙酯（$CH_3COOCH_2CH_3$）的鍵結與結構之敘述，哪個**正確**？
(A) It has 4 pairs of lone pair electrons.
   具有 4 對未鍵結電子對
(B) All four carbon atoms use sp^3 hybrid orbitals for bonding.
   四個碳原子皆用 sp^3 混成軌域鍵結
(C) This compound is a planar molecule.
   此化合物為一平面分子
(D) This molecule has an intermolecular hydrogen bond.
   此分子具有分子間氫鍵
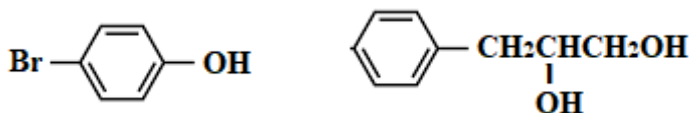(E) The bond angle between C-O-C is 180 degrees.
   其 C-O-C 之鍵角為 180 度

4. Which of the following substances, when oxidized by acidic KMnO₄ solution, can produce 4-methyl-2-pentanone?

下列物質被酸性的 KMnO₄ 溶液氧化，何者可得到 4-甲基-2-戊酮？

(A) CH₃CH₂CH₂CHCH₃
                |
                OH

(B) CH₃C—CH₂CH₂CH₃
       |
       CH₃ (with OH above C)

(C) CH₃CH₂CHCHCH₃
            | |
           CH₃ OH

(D) CH₃CHCH₂CHOH
        | |
       CH₃   CH₃

(E) CH₃CHCH₂CH₂CH₂OH
        |
       CH₃

5. Which of the following reagent <u>could NOT</u> be used to differentiate the following organic compounds?

哪一項試劑**不可以**用於檢驗分別以下有機化合物？

Br—⟨benzene ring⟩—OH   ⟨benzene ring⟩—CH₂CHCH₂OH
                                              |
                                              OH

   (I) AgNO₃ 溶液 solution   (II) KOH 溶液 solution
   (III) 金屬鈉 sodium metal   (IV) KMnO₄ 溶液 solution

(A) I,II,III   (B) I, III   (C) II,IV
(D) I, III, IV   (E) 其他的组合 None of the above.

6. Coordination compounds, also known as complex compounds, are important in catalysis reactions, molecular biology, and medicine. Regarding the coordination number and oxidation states of central atoms in the following compounds, which of the following statements is **correct**?

錯合物又稱配位化合物，其近來在配位催化反應、分子生物學及醫藥方面，有愈來愈重要的趨勢。有關錯合物與錯離子中原子的各項敘述，下列哪個**正確**？

(A) In $[Fe(C_2O_4)_3]^{3-}$, the coordination number of Fe is 3.

    在 $[Fe(C_2O_4)_3]^{3-}$ 中，Fe 之配位數為 3

(B) In $[Ni(CN)_4]^{2-}$, the oxidation state of Ni is +3.

    在 $[Ni(CN)_4]^{2-}$ 中，Ni 之氧化數為 +3

(C) In $[Cr(OH)_4(H_2O)_2]^-$ in alkaline solution, the coordination number of Cr is 6.

    $[Cr(OH)_4(H_2O)_2]^-$ 在鹼性溶液中，Cr 之配位數為 6

(D) The coordination number of tin ions in ammonia solution is usually 2.

    錫離子在氨水溶液中之配位數通常為 2

(E) Dissolve equimolar amounts of $[Co(en)_3]Cl_3$ and $[Pd(NH_3)_4]Cl_2$ in equal volumes of water, and adding excess AgNO₃ solution until precipitation is complete, the latter will have a larger amount of precipitate.

   取等莫耳 $[Co(en)_3]Cl_3$ 與 $[Pd(NH_3)_4]Cl_2$ 分別溶於等量的水中，加入過量硝酸銀溶液至完全沉澱，則後者的沉澱量較大

7. The Group 1A metal sodium easily oxidizes to sodium oxide upon exposure to air. Sodium oxide is soluble in water and readily reacts with water. At room temperature, when solid sodium oxide is separately added to solutions containing the following ions, which ions' concentration remain almost unchanged?

1A 族的金屬鈉接觸空氣後，很容易氧化為氧化鈉。氧化鈉易溶於水也容易與水發生化學反應。室溫下將固體氧化鈉分別加入含下列離子的水溶液中，哪個離子的濃度幾乎沒有變化？

(A) Na^+ (B) Fe^{3+} (C) K^+ (D) H^+ (E) $Cr_2O_7^{2-}$

8. Ethylenediaminetetraacetate, abbreviated as EDTA, has the structure shown below. In an alkaline environment, it forms complex ions with metal ions and can be used to analyze the concentration of metal ions in water. Which of the following statements is **correct**?

乙二胺四乙酸根 (Ethylenediaminetetraacetate) 簡稱 EDTA，結構如下圖所示，在鹼性環境下，與金屬離子形成錯離子，可應用於分析水中金屬離子的濃度。下列敘述，哪個**正確**？

$$^-OOC-CH_2 \diagdown \quad \diagup CH_2-COO^-$$
$$\qquad\qquad :N-CH_2-CH_2-N:$$
$$^-OOC-CH_2 \diagup \quad \diagdown CH_2-COO^-$$
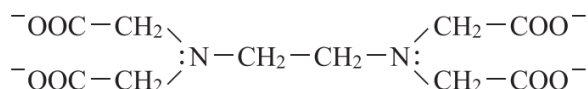
(A) In an alkaline environment, EDTA can at most form a tetradentate ligand.
   EDTA 在鹼性環境下最多可成為四牙配位子

(B) In [Fe(EDTA)]⁻, the oxidation state of iron is + 2.
   [Fe(EDTA)]⁻中，鐵的氧化數為 + 2

(C) In [Ca(EDTA)]²⁻, the coordination number of calcium is 6.
   [Ca(EDTA)]²⁻中，Ca 的配位數為 6

(D) The shape of [Ca(EDTA)]²⁻ is tetrahedral.
   [Ca(EDTA)]²⁻的形狀為四面體形

(E) [Ca(EDTA)]²⁻ has 2 isomers.
   [Ca(EDTA)]²⁻有 2 個異構物

9. Five metals are given the symbols of **A**, **G**, **M**, **R**, and **Z**, and the following reactions are observed:

五種金屬分別給予代號 A、G、M、R 及 Z，進行下列反應：

(1) **A**, **M**, and **R** dissolve in hydrochloric acid; **G** and **Z** do not dissolve in hydrochloric acid.
   A、M 及 R 可溶於鹽酸，G 與 Z 不溶於鹽酸。

(2) **M** decomposes water violently at room temperature; **A** decomposes water at room temperature but the reaction is milder; **R** reacts with water at high temperature.
   M 在常溫下會激烈地分解水；A 在常溫下可分解水，但此反應較緩和；R 在高溫水中會起反應。

(3) A piece of **Z** is placed in an aqueous solution containing **G** ions; **G** is displaced and **Z** dissolves.
   將一片 Z 投於含 G 離子的水溶液中，G 被析出，Z 溶解。

(4) **R** and **G** ions can form an electrochemical cell with **R** metal as the anode.
   R 與 G 離子可組成一電化電池，R 金屬當陽極。

   Based on the above reactions (1) to (4), what is the order of the metal ions in terms of their tendency to be ionized?
   由上述(1)～(4)反應中，排出五種金屬離子化傾向之順序為何？

   (A) M > A > R > Z > G   (B) A > M > R > Z > G

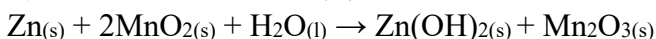   (C) M > A > Z > R > G   (D) M > G > R > Z > A

   (E) M > Z > A > R > G

10. Which of the following statements about the oxidation states of elements is **correct**?
下列有關各元素氧化數之敘述，哪個**正確**？
(A) Ag_2S, $Na_2S_2O_3$, SO_2, SO_3: The oxidation state of S is +2 in each of them.
　　Ag_2S、$Na_2S_2O_3$、SO_2、SO_3：其中 S 的氧化數均為 +2
(B) NaCl, Na_2O_2, NaOH, NaH: The oxidation state of Na is +2 in each of them.
　　NaCl、Na_2O_2、NaOH、NaH：其中 Na 的氧化數均為 +2
(C) $K_2Cr_2O_7$, K_2CrO_4, $HClO_3$, $HClO_4$: The oxidation state of O is -2 in each of them.
　　$K_2Cr_2O_7$、K_2CrO_4、$HClO_3$、$HClO_4$：其中 O 的氧化數均為 -2
(D) H_2O_2, $KMnO_4$, F_2O, MgO: The oxidation state of O is -1 in each of them.
　　H_2O_2、$KMnO_4$、F_2O、MgO：其中 O 的氧化數均為 -1
(E) KH, H_2O_2, CH_4, H_2O: The oxidation state of H is +1 in each of them.
　　KH、H_2O_2、CH_4、H_2O：其中 H 的氧化數均為 +1

11. Alkaline batteries have the characteristics of large capacity, high discharge, and stable current, and are therefore widely used. Zinc-lithium alkaline batteries use a zinc hydroxide solution as the electrolyte. The overall reaction of the battery is:
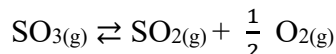鹼性電池具有容量大、放電多、電流穩的特點，因而得到廣泛的使用；鋅鋰鹼性電池以氫氧化鋅水溶液為電解液，其電池的總反應式為:
$Zn_{(s)} + 2MnO_{2(s)} + H_2O_{(l)} \rightarrow Zn(OH)_{2(s)} + Mn_2O_{3(s)}$
Which of the following statements is **correct**?
下列敘述，何者**正確**？
(A)　During battery discharge, Mn loses electrons
　　電池放電時，Mn 失去電子
(B)　The reaction at the cathode is: $2MnO_{2(s)} + H_2O_{(l)} + 2e^- \rightarrow Mn_2O_{3(s)} + 2OH^-_{(aq)}$
　　電池陰極的反應式為 $2MnO_{2(s)} + H_2O_{(l)} + 2e^- \rightarrow Mn_2O_{3(s)} + 2OH^-_{(aq)}$
(C)　During battery discharge, electrons flow from the anode to the cathode through an external circuit
　　電池放電時，電子由正極經由外電路流向負極
(D)　The disadvantage of alkaline batteries is the generation of hydrogen gas during discharge, causing polarization and unstable current
　　鹼性電池的缺點為放電時產生氫氣，即極化效應，電流較不穩定
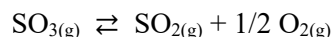(E)　It is a secondary battery and can be charged and discharged multiple times
　　為二次電池，可多次充、放電使用

12. 8.00 g of SO_3 gas was placed in a vacuum container and decomposed at 627 °C as follows:
$$SO_{3(g)} \rightleftarrows SO_{2(g)} + \frac{1}{2} O_{2(g)}$$
At equilibrium, the total pressure of the gas was measured to be 1.80 atm, and the total density was 1.56 g/L. What is the equilibrium constant K_p of this reaction?
一真空容器中置入 8.00 g 的 SO_3 氣體，在 627 °C 下發生分解反應如下：
$$SO_{3(g)} \rightleftarrows SO_{2(g)} + 1/2 O_{2(g)}$$
達平衡時測得氣體的總壓為 1.80 atm，總密度為 1.56 g/L，求此反應的平衡常數 K_p 為若干？
(A) 0.6　　　　　　　　(B) 0.8　　　　　　　　(C) 1.2
(D) 1.6　　　　　　　　(E) 1.8

13. 0.168 g sample of quicklime CaO was dissolved in a large amount of water to form 1500 mL of solution. What is the pH of the solution when it is cooled to 25 °C?
有一 0.168 g 的生石灰 CaO 樣品溶於大量水中，形成 1500 mL 的溶液，待其降溫至 25 °C 時，溶液 pH 值為若干？
(A) 10.3　　　　　　　　(B) 10.6　　　　　　　　(C) 11.3
(D) 11.6　　　　　　　　(E) 12.3

14. The rate law for the reaction $2X + Y \rightarrow 2Z$ is $r = k[X]^2[Y]$. Given that when [X] = 1M and [Y]= 3M, the initial reaction rate is R. If the temperature and total pressure remain constant, and [X] remains the same while [Y]= 9M, what will the initial reaction rate be?
反應 $2X + Y \rightarrow 2Z$ 的速率定律為 $r = k[X]^2[Y]$，設參與反應的[X] = 1M，[Y]= 3M 時，反應初速率為 R；若在溫度、總壓力維持不變的情況下，參與反應的 [X] 不變，[Y]= 9M, 則反應初速率將變為多少？

(A) 9R
(B) 3R
(C) $\frac{72}{125}$ R
(D) $\frac{24}{125}$ R
(E) $\frac{8}{125}$ R

15. By measuring the relationship between concentration and time, we can use the data to explore the relationship between concentration and the rate of a chemical reaction. For example, the relationship between the concentration of reactant X and the reaction time is shown in Table 1. Which of the following statements is **correct**?
經由測定濃度與時間的關係，我們可以由數據探討濃度與某化學反應速率之間的關係。例如：某反應中，反應物 X 的濃度與反應經過的時間關係如表一，下列敘述哪個**正確**？

Table 1

濃度 [X] (M)	0.64	0.52	0.40	0.28
時間 Time (s)	0	20	40	60

(A) It is a first-order reaction with respect to X
   對 X 為一級反應
(B) It is a second-order reaction with respect to X
   對 X 為二級反應
(C) The reaction rate constant is 6×10^{-3} M/s
   反應速率常數為 6×10^{-3} M/s
(D) The units of the rate constant and the reaction rate are different
   速率常數與反應速率的單位不同
(E) After 100 seconds, [X] is 0.16 M
   時間為 100 秒後，[X] 為 0.16 M

16. For the following ten substances, determine which statements is **correct**:
就下列十種物質中，判斷下列敘述何者**正確**？
   CH_2Cl_2, XeF_4, N_2F_2, $C_2H_2Cl_2$, H_2O_2, S_2Cl_2, C_2H_4, BF_3, N_2O_4, HCHO

(A) The carbon atom in CH_2Cl_2 forms bonds using sp^2 hybrid orbitals.
   CH_2Cl_2 的碳原子，是以 sp^2 混成軌域來形成鍵結的化合物
(B) N_2F_2 is a compound with cis-trans isomers
   N_2F_2 分子為有順反異構物的化合物
(C) Two of the ten substances have intramolecular hydrogen bonds
   上述十種物質有兩種化合物具有分子內氫鍵
(D) A compound with a structure similar to N_2O_4 is H_2O_2
   與 N_2O_4 結構類似的化合物為 H_2O_2
(E) There are no multiple bonds in N_2F_2, $C_2H_2Cl_2$, C_2H_4, and N_2O_4
   N_2F_2、$C_2H_2Cl_2$、C_2H_4、N_2O_4 中並無多重鍵

17. Which of the following molecules has polar covalent bonds but is **nonpolar** molecule?
下列哪個分子，具有極性的共價鍵，但分子**不具有**極性？
(A) NO_2
(B) CO_2
(C) N_2O
(D) SO_2
(E) O_2

18. Pentane (C_5H_{12}) and hexane (C_6H_{14}) can form an ideal solution. At 25 °C, the vapor pressures of pentane and hexane are 525 torr and 150 torr, respectively. Now a solution is made by mixing 24 mL of pentane (density 0.6 g/mL) and 40 mL of hexane (density 0.645 g/mL).　Which of the following statements is correct?
戊烷（C_5H_{12}）與己烷（C_6H_{14}）混合可形成理想溶液，在 25 °C 時，戊烷與己烷的蒸氣壓分別為 525 torr 與 150 torr，今有一溶液由戊烷（密度 0.6 g/mL）24 mL 與己烷（密度 0.645 g/mL）40 mL 混合而成，下列相關敘述哪個**正確**？

  (A) The boiling point of pentane is higher than that of hexane
     戊烷的沸點高於己烷
  (B) The mole fraction of pentane in the solution phase is 0.6
     溶液相中戊烷的莫耳分率為 0.6
  (C) The vapor pressure of the solution is 337.5 torr
     溶液的蒸氣壓為 337.5 torr
  (D) The mole fraction of pentane in the vapor phase is 0.7
     溶液的蒸氣相中戊烷的莫耳分率為 0.7
  (E) When pentane and hexane are mixed, the temperature of the solution increases
     戊烷與己烷混合時，溶液的溫度上升

19. If glucose (I), magnesium bromide (II), sodium chloride (III), and acetic acid (IV) are used to prepare equal volume solutions with the same osmotic pressure at 25 °C, what is the correct order of the required masses from largest to smallest?
(Molecular weight: $C_6H_{12}O_6 = 180$、$CH_3COOH = 60$; formula weight: $MgBr_2 = 184$, $NaCl = 58.5$)
若用葡萄糖（I）、溴化鎂（II）、氯化鈉（III）、醋酸（IV）等四種化合物，在 25 °C 下製備相同滲透壓等體積溶液，所需質量由大至小排序，則下列哪一選項**正確**？
（分子量：$C_6H_{12}O_6 = 180$、$CH_3COOH = 60$；式量：$MgBr_2 = 184$，$NaCl = 58.5$）

(A) I > II > III > IV   (B) II > I > IV > III   (C) I > IV > III > II
(D) II > I > III > IV   (E) I > II > IV > III

20. Camphor ($C_{10}H_{16}O$) and naphthalene ($C_{10}H_8$) are waxy crystalline substances with a strong aroma, commonly used as insect repellents. The melting point of camphor is 178.8 °C. At 200 °C, 1.60 g of naphthalene is added to 10.0 g of camphor, forming a homogeneous mixture.　The freezing point of the mixture decreases by 50.0 °C. A certain organic compound weighing 1.20 g is dissolved in 10.0 g of camphor using the same method, and the freezing point of the mixture decreases by 40.0 °C. What is the molecular weight of this organic compound?
樟腦（$C_{10}H_{16}O$）與萘（$C_{10}H_8$）都是具有刺激香氣的蠟狀結晶物，常作為驅蟲劑。已知樟腦的溶點為 178.8 °C。在 200 °C 時將 1.60 g 的萘加入 10.0 g 的樟腦中，形成均勻混合物，則此樟腦混合物的凝固點下降了 50.0 °C。將某種有機物 1.20 g 以同樣步驟溶於 10.0 g 的樟腦中，樟腦混合物的凝固點下降了 40.0 °C，則此有機物的分子量為多少？

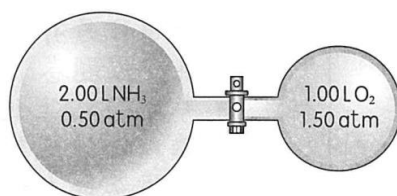(A) 56   (B) 77   (C) 120
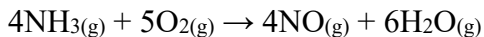(D) 137   (E) 213

圖 1

21. Industrially, nitric acid is produced by the Ostwald process. The first step is the oxidation of ammonia to form nitric oxide.　The chemical reaction is as follows:

$4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$

A reaction apparatus is shown in Figure 1. After opening the valve, assuming the reaction proceeds at a constant temperature with a yield of 75%, calculate the partial pressure of NO after the reaction.

工業上以奧士華法製造硝酸，其反應的第一步是將氨氣氧化生成一氧化氮，化學反應式如下：$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$，今有一反應裝置如圖 1 所示，打開活栓後，假設在定溫下反應可達 75% 的產率，試計算反應後 NO 的分壓為若干 atm？

(A) 0.20 atm　　　　　(B) 0.25 atm　　　　　(C) 0.40 atm
(D) 0.60 atm　　　　　(E) 0.83 atm

22. At 0 °C, a certain sealed container with a volume of 22.4L contains helium, nitrogen, and hydrogen gases. The total pressure is 2 atm, the partial pressure of helium is 0.5 atm, and the amount of nitrogen is 0.5 mol. Which of the following statements is **correct**?

0 °C 時，22.4 L 的某密閉容器中裝有氦氣、氮氣及氫氣三種氣體，已知總壓為 2 atm，氦氣之分壓為 0.5 atm，氮氣有 0.5 mol，下列敘述哪個 **正確**？

(A) The partial pressure of nitrogen is 1.0 atm
氮氣分壓為 1.0 atm
(B) The partial pressure of hydrogen is the highest among the three gases.
三種氣體中以氫氣之分壓最大
(C) The mole fraction of helium is 0.5
氦氣之莫耳分率為 0.5
(D) The weight ratio (helium: nitrogen: hydrogen) is 2 : 4 : 7
重量比（氦氣：氮氣：氫氣）= 2 : 4 : 7
(E) The average molecular weight of the gas mixture is 18
混合氣體之平均分子量為 18

23. After burning pure carbon in excess oxygen, the mole fractions of the resulting gases are as follows: CO_2 72%, CO 16%, and O_2 12%.　What is the mole ratio of pure carbon to oxygen in the original reactants?

純碳與過量的氧氣進行燃燒後，所得的產物中，各成分氣體的莫耳分率分別為 CO_2 占 72%、CO 占 16%、O_2 占 12%，請推算原來反應物中純碳與氧氣的莫耳數比例為何？

(A) 4:5

(B) 10:11

(C) 15:16

(D) 18:19

(E) 22:23

24. At room temperature, 0.2 mol each of potassium and aluminum are placed in two separate containers, each containing 100 mL of 1.0 M hydrochloric acid. What is the volume ratio of the gas produced by potassium and aluminum?

室溫下，取鉀與鋁各 0.2 莫耳，分別放入兩個各含有 100 毫升 1.0 M 鹽酸的容器中，鉀與鋁所生成的氣體體積比為何？

(A) 1:3   (B) 1:2   (C) 1:1
(D) 2:1   (E) 3:1

25. When an electron in an atom transitions from an excited state to the ground state, the excess energy is released in the form of light. This phenomenon is a type of electronic transition. Among the following principal quantum numbers n, which electronic transition produces the **shortest** wavelength in the hydrogen atom?

當原子的電子由激發態躍遷至基態時，會將多餘的能量以光的形式釋出，這種現象為電子躍遷的一種。氫原子在下列哪一種主量子數 n 之間的電子躍遷，所產生光譜的波長**最短**？

(A) n＝4 → n＝2   (B) n＝3 → n＝1   (C) n＝4 → n＝3
(D) n＝3 → n＝2   (E) n＝2 → n＝1