

**2023 年第三十八屆成大數理比賽 - 化學**  
**38<sup>th</sup> NCKU Science and Mathematics Competition 2023 – Chemistry**

1. Which of the following changes will *not* affect the total pressure of gas in a container, assuming all other factors remain constant?  
假設所有其他因素保持不變，以下哪項變化不會影響容器中氣體的總壓力？
- A). The frequency of collisions of molecules with the walls is increased.  
分子與壁碰撞的頻率增加。
- B). The average velocity of the molecules is lowered.  
分子的平均速度降低。
- C). The temperature of the sample is altered.  
樣品的溫度改變了。
- D). Half of the molecules are replaced by an equal number of molecules of a gas with a different molecular weight.  
一半的分子被相同數量的不同分子量的氣體分子所取代。
- E). The total number of molecules is altered.  
分子總數改變。
2. Which one of the following reactions shows that  $\Delta H$  is approximately (or exactly) equal to  $\Delta E$ ?  
對於以下哪一個反應， $\Delta H$  大約（或恰好）等於  $\Delta E$ ？
- A).  $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightarrow 2\text{HBr}(\text{g})$
- B).  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$
- C).  $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- D).  $2\text{H}(\text{g}) + \text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- E).  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
3. Select the *correct* set of quantum numbers ( $n, l, m_l, m_s$ ) for the highest energy electron in the ground state of potassium, K.  
基態鉀(K)最高能量電子的正確量子數集 ( $n, l, m_l, m_s$ ) 為下列哪一組？
- A). 4, 1, -1,  $\frac{1}{2}$                       B). 4, 1, 0,  $\frac{1}{2}$                       C). 4, 0, 1,  $\frac{1}{2}$
- D). 4, 0, 0,  $\frac{1}{2}$                       E). 4, 1, 1,  $\frac{1}{2}$

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4. Combustion of a fat will release more energy than combustion of an equal mass of carbohydrate because

脂肪的燃燒比等量碳水化合物的燃燒釋放更多的能量，因為

A). fats contain more bonds to oxygen than carbohydrates.

脂肪比碳水化合物含有更多的碳-氧鍵。

B). fats contain fewer bonds to oxygen than carbohydrates.

脂肪比碳水化合物含有更少的碳-氧鍵。

C). the total energy of the carbon-carbon and carbon-hydrogen bonds in fats is greater than the energy content of the carbon-oxygen and oxygen-hydrogen bonds in the reaction products (carbon dioxide and water).

脂肪中碳-碳鍵和碳-氫鍵的總能量大於反應產物（二氧化碳和水）中碳-氧和氧-氫鍵的能量。

D). the total energy of the carbon-carbon and carbon-hydrogen bonds in fats is greater than the energy content of the bonds in carbohydrates.

脂肪中碳-碳鍵和碳-氫鍵的總能量大於碳水化合物中所有鍵的能量總和。

E). fats have higher molar masses than carbohydrates.

脂肪比碳水化合物具有更高的摩爾質量。

5. Select the compound with the lowest (i.e., least negative) lattice energy.

下列哪個化合物具有最低晶格能(最小負值)?

A). CsBr(s)

B). NaCl(s)

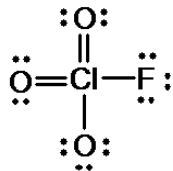
C). SrO(s)

D). CaO(s)

E). KBr(s)

6. In the following Lewis structure for ClO<sub>3</sub>F, chlorine has a formal charge of \_\_\_\_ and an oxidation number of \_\_\_\_.

下面 ClO<sub>3</sub>F 的路易斯結構中，氯的形式電荷為 \_\_\_\_，氧化數為 \_\_\_\_。



A). 7, 7

B). 7, -1

C). 1, 1

D). 1, -1

E). 1, 7

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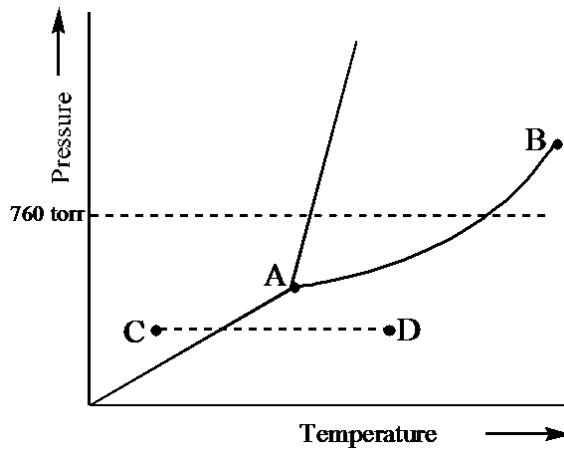
7. According to molecular orbital theory, what is the bond order of the  $O_2^+$  ion?

根據分子軌道理論， $O_2^+$  離子的鍵級是多少？

- A). 5.5                      B). 5                      C). 4                      D). 2.5  
E). 1.5

8. Examine the phase diagram for the substance Bogusium (Bo) and select the *correct* statement.

檢查物質 Bogusium (Bo) 的相圖並選擇正確的陳述。



- A). Bo(s) has a lower density than Bo(l).  
Bo(s)的密度低於Bo(l)。
- B). The triple point for Bo is at a higher temperature than the melting point for Bo.  
Bo的三相點溫度高於Bo的熔點。
- C). Bo changes from a solid to a liquid as one follows the line from C to D.  
當沿著C到D的線時，Bo從固體變為液體。
- D). Bo changes from a liquid to a gas as one follows the line from C to D.  
沿著C到D的線時，Bo從液體變為氣體。
- E). Point B represents the critical temperature and pressure for Bo.  
B點代表Bo的臨界溫度和壓力。

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9. Consider the expression below, showing the terms which contribute to the heat of solution,  $\Delta H_{\text{soln}}$ :

$$\Delta H_{\text{soln}} = \Delta H_{\text{solute}} + \Delta H_{\text{solvent}} + \Delta H_{\text{mix}}$$

Which of the following sets correctly shows the signs (positive or negative) of the three terms on the right hand side of the equation?

上面方程式顯示出會貢獻溶解熱( $\Delta H_{\text{soln}}$ )的三項熱源，以下哪一組正確顯示了方程式右側三項的符號（正或負）？

- A).  $\Delta H_{\text{solute}} > 0$ ;  $\Delta H_{\text{solvent}} > 0$ ;  $\Delta H_{\text{mix}} > 0$     B).  $\Delta H_{\text{solute}} < 0$ ;  $\Delta H_{\text{solvent}} < 0$ ;  $\Delta H_{\text{mix}} < 0$   
C).  $\Delta H_{\text{solute}} > 0$ ;  $\Delta H_{\text{solvent}} > 0$ ;  $\Delta H_{\text{mix}} < 0$     D).  $\Delta H_{\text{solute}} < 0$ ;  $\Delta H_{\text{solvent}} < 0$ ;  $\Delta H_{\text{mix}} > 0$   
E).  $\Delta H_{\text{solute}} < 0$ ;  $\Delta H_{\text{solvent}} > 0$ ;  $\Delta H_{\text{mix}} < 0$

10. Which of the following oxides is most basic?

以下哪種氧化物鹼性最強？

- A).  $\text{As}_2\text{O}_3$     B).  $\text{P}_4\text{O}_{10}$     C).  $\text{Sb}_2\text{O}_3$     D).  $\text{Sb}_2\text{O}_5$     E).  $\text{NO}_2$

11. Most of the alkali metal salts are soluble in water while many alkaline earth salts have very low solubilities. Why is this so?

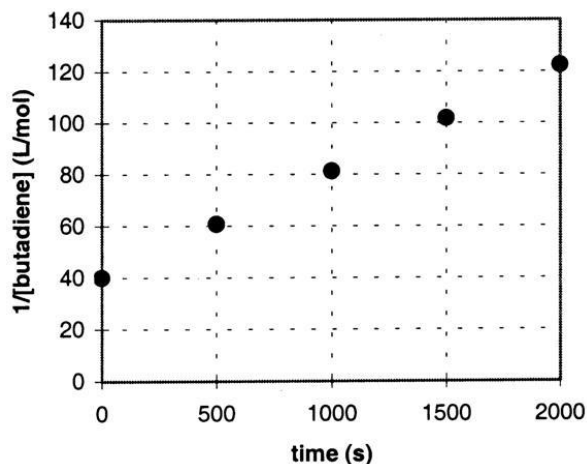
大多數鹼金屬鹽可溶於水，而許多鹼土金屬鹽的溶解度很低。為什麼會這樣？

- A). The alkali metal cations are smaller than the alkaline earth cations and are more easily hydrated.  
鹼金屬陽離子比鹼土金屬陽離子小，更容易水合。
- B). The alkali metals have lower ionization energies than alkaline earth elements.  
鹼金屬的電離能低於鹼土元素。
- C). The alkaline earth salts have much greater lattice energies than the alkali metal salts.  
鹼土金屬鹽的晶格能比鹼金屬鹽大得多。
- D). The alkaline earth metals have greater heats of atomization than the alkali metals.  
鹼土金屬比鹼金屬有更大的霧化熱。
- E). Alkaline earth cations have very low heats of hydration.  
鹼土金屬陽離子的水化熱非常低。

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12. The gas-phase conversion of 1,3-butadiene to 1,5-cyclooctadiene,  $2\text{C}_4\text{H}_6 \rightarrow \text{C}_8\text{H}_{12}$ , was studied, providing data for the plot shown in the following graph of  $1/[\text{butadiene}]$  versus time. Which of the following statements is (are) *correct* regarding this experiment?

在1,3-丁二烯反應到1,5-環辛二烯的氣相轉化實驗中， $2\text{C}_4\text{H}_6 \rightarrow \text{C}_8\text{H}_{12}$ ，實驗數據提供了 $1/[\text{丁二烯}]$ 對時間的關係圖，如下圖所示。則下列哪個敘述是正確的？



- A). This plot confirms that the reaction is first order.  
該圖證實反應是一級反應。
- B). This plot confirms that the reaction is zero order.  
該圖證實反應是零級反應。
- C). The rate constant,  $k$ , is  $4.2 \times 10^{-2} \text{ L mol}^{-1} \text{ s}^{-1}$ .  
反應速率常數,  $k$ , 為  $4.2 \times 10^{-2} \text{ L mol}^{-1} \text{ s}^{-1}$ 。
- D). The initial concentration of 1,3-butadiene in this experiment is  $0.050 \text{ mol L}^{-1}$ .  
此實驗中1,3-丁二烯的初始濃度為  $0.050 \text{ mol L}^{-1}$ 。
- E). None of these is correct.  
以上都不正確。

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13. The gas-phase reaction  $\text{CH}_3\text{NC} \rightarrow \text{CH}_3\text{CN}$  has been studied in a closed vessel, and the rate equation was found to be:  $\text{Rate} = -\Delta[\text{CH}_3\text{NC}]/\Delta t = k[\text{CH}_3\text{NC}]$ . Which one of the following actions is least likely to cause a change in the rate of the reaction?

在密閉容器中進行了氣相反應  $\text{CH}_3\text{NC} \rightarrow \text{CH}_3\text{CN}$ ，所得速率方程為： $\text{Rate} = -\Delta[\text{CH}_3\text{NC}]/\Delta t = k[\text{CH}_3\text{NC}]$ 。以下哪一項行動最不可能引起反應速率的變化？

A). lowering the temperature.

降低溫度。

B). adding a catalyst.

加入催化劑。

C). using a larger initial amount of  $\text{CH}_3\text{NC}$  in the same vessel.

在同一容器中使用較大初始量的 $\text{CH}_3\text{NC}$ 。

D). using a bigger vessel, but the same initial amount of  $\text{CH}_3\text{NC}$ .

使用更大的容器，但 $\text{CH}_3\text{NC}$ 的初始量相同。

E). continuously removing  $\text{CH}_3\text{CN}$  as it is formed.

在 $\text{CH}_3\text{CN}$ 形成時不斷地將之去除。

14. Which of the following is the *correct* relationship among the concentrations of species present in a 1.0 M aqueous solution of the weak acid represented by HA? 在1.0 M的HA弱酸水溶液中，其存在的物種濃度之間的關係，下列哪組是正確的？

A).  $[\text{H}_2\text{O}] > [\text{A}^-] \sim [\text{H}_3\text{O}^+] > [\text{HA}] > [\text{OH}^-]$

B).  $[\text{H}_2\text{O}] > [\text{HA}] > [\text{A}^-] > [\text{H}_3\text{O}^+] > [\text{OH}^-]$

C).  $[\text{HA}] > [\text{H}_2\text{O}] > [\text{A}^-] > [\text{H}_3\text{O}^+] > [\text{OH}^-]$

D).  $[\text{H}_2\text{O}] > [\text{HA}] > [\text{A}^-] \sim [\text{H}_3\text{O}^+] > [\text{OH}^-]$

E).  $[\text{HA}] > [\text{H}_2\text{O}] > [\text{A}^-] \sim [\text{H}_3\text{O}^+] > [\text{OH}^-]$

15. The salt BX, when dissolved in water, produces an acidic solution. Which of the following could be *true*?

鹽 BX 溶於水時會產生酸性溶液，以下哪項可能是正確的？

A). HX is a weak acid. (HX是一種弱酸。)

B). The cation  $\text{B}^+$  is a weak acid. (陽離子 $\text{B}^+$ 是弱酸。)

C). HX is a strong acid. (HX是強酸。)

D). Both HX and the cation  $\text{B}^+$  are weak acids (HX和陽離子 $\text{B}^+$ 都是弱酸。)

E). All of these could be true. (以上可能皆對。)

16. Which of the following solutions will be the best buffer at a pH of 9.26? ( $K_a$  for

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$\text{HC}_2\text{H}_3\text{O}_2$  is  $1.8 \times 10^{-5}$ ;  $K_b$  for  $\text{NH}_3$  is  $1.8 \times 10^{-5}$ .)

以下哪種溶液可以產生pH值為9.26的最好的緩衝液? ( $\text{HC}_2\text{H}_3\text{O}_2$ 的 $K_a$ 為 $1.8 \times 10^{-5}$ ;  $\text{NH}_3$ 的 $K_b$ 為 $1.8 \times 10^{-5}$ )

- A).  $0.20M \text{NH}_3$  and  $0.20M \text{NH}_4\text{Cl}$       B).  $5.0M \text{HC}_2\text{H}_3\text{O}_2$  and  $5.0M \text{NH}_4\text{Cl}$   
C).  $5.0M \text{HC}_2\text{H}_3\text{O}_2$  and  $5.0M \text{NH}_3$       D).  $5.0M \text{NH}_3$  and  $5.0M \text{NH}_4\text{Cl}$   
E).  $0.20M \text{HC}_2\text{H}_3\text{O}_2$  and  $0.20M \text{NaC}_2\text{H}_3\text{O}_2$

17. As water is heated, its pH decreases. This means that

當水被加熱時，它的 pH 值會降低。這表示

- A).  $[\text{OH}^-] > [\text{H}^+]$   
B).  $[\text{H}^+] > [\text{OH}^-]$   
C). The water is no longer neutral. (水不再是中性的。)  
D). The ion-product constant,  $K_w$ , of water decreases. (水離子積  $K_w$  減小。)  
E). None of these is correct. (以上皆非。)

18. A 200.0 mL sample of the weak acid  $\text{H}_3\text{A}$  ( $0.100 M$ ) is titrated with

$0.200 M$  of  $\text{NaOH}$ . What are the major species after 220.0 mL of  $0.200 M$   $\text{NaOH}$  is added.

200.0 mL 的弱酸  $\text{H}_3\text{A}$  ( $0.100 M$ ) 樣品用  $0.200 M$  的氫氧化鈉溶液滴定，當 220.0 mL  $0.200 M$  的氫氧化鈉加入後，則此時主要成份有哪些?

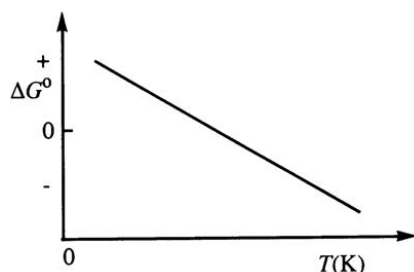
- A).  $\text{A}^{3-}$       B).  $\text{OH}^-$ ,  $\text{A}^{3-}$       C).  $\text{H}_2\text{A}^-$ ,  $\text{HA}^{2-}$       D).  $\text{HA}^{2-}$   
E).  $\text{HA}^{2-}$ ,  $\text{A}^{3-}$

19. Consider the figure below which shows  $\Delta G^\circ$  for a chemical process plotted

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against absolute temperature. Which one of the following is an *incorrect* conclusion, based on the information in the diagram?

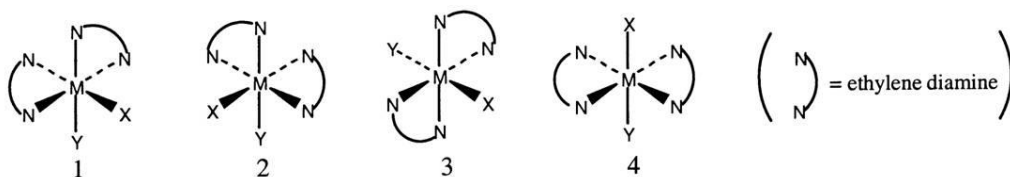
考慮下圖，該圖顯示了一化學反應過程的 $\Delta G^\circ$ 對絕對溫度的圖，根據圖中的信息，下列哪一項的結論是不正確的？



- A).  $\Delta H^\circ > 0$   
 B).  $\Delta S^\circ > 0$   
 C). The reaction is spontaneous at high temperatures.  
 此反應在高溫下是自發的。  
 D).  $\Delta S^\circ$  increases with temperature while  $\Delta H^\circ$  remains constant.  
 $\Delta S^\circ$  隨溫度升高而  $\Delta H^\circ$  保持不變。  
 E). There exists a certain temperature at which  $\Delta H^\circ = T\Delta S^\circ$ .  
 在某一溫度下  $\Delta H^\circ = T\Delta S^\circ$ 。

20. Consider the following octahedral complex structures, each involving ethylene diamine and two different unidentate ligands X and Y. Which one of the following statements about these structures is *incorrect*?

考慮以下八面體複雜的結構，每個結構都與乙二胺及兩個不同的單配體 X 和 Y 鍵結。以下哪一項關於這些結構的陳述是不正確的？



- A). Structures 1 and 2 are optical isomers. (結構 1 和 2 是光學異構物。)  
 B). Structures 1 and 3 are optical isomers. (結構 1 和 3 是光學異構物。)  
 C). Structures 1 and 3 are different complexes. (結構 1 和 3 是不同的複合物。)  
 D). Structures 1 and 4 are geometrical isomers. (結構 1 和 4 是幾何異構體。)  
 E). Structures 3 and 4 are the same complex. (結構 3 和 4 是相同的複合體。)



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21. The crystal field splitting energy,  $\Delta$ .

關於晶體場分裂能量， $\Delta$ ，下列敘述哪一項是對的。

A). is larger for tetrahedral complexes than for octahedral complexes.

四面體複合物比八面體複合物大。

B). depends on the metal but not on the ligand.

取決於金屬本身而不是配體。

C). determines the color of a complex.

決定複合物的顏色。

D). is larger for ionic ligands like chloride than for molecular ligands like carbon monoxide, CO.

對於離子配體(如氯化物)比對於分子配體(如一氧化碳，CO)更大。

E). determines the charge of a complex.

確定複合物的電荷。

22. An isotope with a high value of  $N/Z$  will tend to decay through

具有高  $N/Z$  (中子數/質子數)值的同位素會傾向於何種衰變?

A).  $\alpha$  decay. ( $\alpha$ 衰變。)

B).  $\beta$  decay. ( $\beta$ 衰變。)

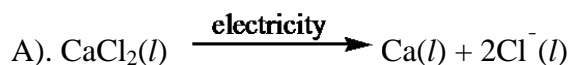
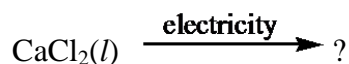
C). positron decay. (正電子衰變。)

D). electron capture. (電子捕獲。)

E).  $\gamma$  decay. ( $\gamma$ 輻射衰變。)

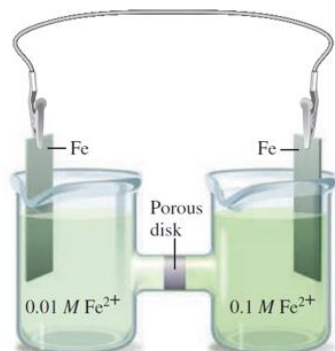
23. Predict the products by completing a balanced equation for the following electrolyzed reaction.

下列電解反應的平衡方程那一個是正確的?



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24. A concentration cell containing iron electrodes and different concentrations of  $\text{Fe}^{2+}$  ion in the two compartments, which is shown as below. Which of the following statements is *not true*?



上圖所示的濃差電池在兩個隔室中包含鐵電極和不同濃度的  $\text{Fe}^{2+}$  離子，則下列敘述哪項是錯的？

- A). The electron is transferred from the left compartment to the right compartment.  
電子從左隔室轉移到右隔室。
- B). The potential for this cell is 0.0296 V.  
此電池的電動勢為 0.0296 V。
- C). The iron metal will be deposited on the right electrode.  
鐵金屬將沉積在右側電極上。
- D). The oxidation occurs in the left compartment, which is the cathode.  
氧化反應發生在左隔室，也就是陰極。
- E). The  $[\text{Fe}^{2+}]$  in the both compartments will eventually be equalized.  
兩隔室中的  $[\text{Fe}^{2+}]$  最終會是一樣。
25. Which of the following is optically active (that is, chiral)?  
以下哪一化合物具有光學活性或旋光性（即對掌性）？
- |                              |                             |                              |
|------------------------------|-----------------------------|------------------------------|
| A). 3-chloropentane<br>3-氯戊烷 | B). 1-bromopentane<br>1-溴戊烷 | C). 2-chloropentane<br>2-氯戊烷 |
| D). dichloromethane<br>二氯甲烷  | E). dimethylamine<br>二甲基胺   |                              |