

2020 澳門高中學生化學競賽試題
High school chemistry competition – Macau 2020

Question	1	2	3	4	5	6	7	8	9		Point total
points	30	10	11	11	5	5	11	9	8		100
scores											
Grader											

Question 1	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8
Answer(s)								
Question 1	1-9	1-10	1-11	1-12	1-13	1-14	1-15	
Answer(s)								

Relative molecular mass, g/mol																He 4.003			
H 1.008															He 4.003				
Li 6.941	Be 9.012													B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18
Na 22.99	Mg 24.31													Al 26.98	Si 28.09	P 30.97	S 32.07	Cl 35.45	Ar 39.95
K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 52.00	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.69	Cu 63.55	Zn 65.39	Ga 69.72	Ge 72.61	As 74.92	Se 78.96	Br 79.90	Kr 83.80		
Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 98.91	Ru 101.1	Rh 102.9	Pd 106.4	Ag 107.9	Cd 112.4	In 114.8	Sn 118.7	Sb 121.8	Te 127.6	I 126.9	Xe 131.3		
Cs 132.9	Ba 137.3	La-Lu	Hf 178.5	Ta 180.9	W 183.9	Re 186.2	Os 190.2	Ir 192.2	Pt 195.1	Au 197.0	Hg 200.6	Tl 204.4	Pb 207.2	Bi 209.0	Po [210]	At [210]	Rn [222]		
Fr [223]	Ra [226]	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt											

Student full name: _____

Seat number: _____

Student ID number: _____

High school: _____

Contact phone number: _____

This paper consists of eight 8 pages.

Question 1 (30 points)

Multiple choice questions: each question has 1 to 2 good answers; write your answers on answer sheet on the front page.

- 1-1. According to a report published in "Nature", at the end of May 2020, two laboratories reported using cryo-electron microscopy to produce for the first time the clearest image to identify a single atom in a protein. The resolution of the electron microscope reported on this breakthrough may reach
- A · 1.2 pm B · 1.2 nm
C · 1.2 Å D · 1.2 μm
- 1-2. The research fields recognized by the Nobel Prize in Chemistry in 2019 are
- A · Lithium ion battery B · Design and synthesis of molecular machines
C · Mechanism of cell interactions under oxygen D · Invention of blue emitting diode
- 1-3. Under the condition of constant temperature and constant volume, the reaction $A(g)+B(g) \rightleftharpoons C(g)+D(g)$ has reached equilibrium. Changing the conditions can increase the positive reaction rate is/are
- A · Decrease in [C] B · Increase in [D]
C · Decrease in [B] D · Increase in [A]
- 1-4. The correct description about molecular geometry is
- A · Linear in KrF_2 B · Linear in O_2F_2
C · Trigonal planar in $Cd(CN)_4^{2-}$ D · Square planar in $Ni(CN)_4^{2-}$
- 1-5. At room temperature, both beakers **A** and **B** contain 20 mL of acetic acid solution ($pK_a = 4.75$) with $pH=4$. Add water to the beaker **B** to dilute the solution to $pH=5$. The description of the solution obtained in the two beakers is correct
- A · Solution volume: $10V_A = V_B$ B · $[H^+]$ from electrolysis of water: $10c(H^+)_A = c(H^+)_B$
C · When neutralized by the same [NaOH] to A & B, the pH of the resultant solution: $A > B$
D · When reacted with 15 mL NaOH of $pH = 10$, the pH of the resultant solution: $A > B$
- 1-6. It is known that the relative atomic mass of gallium is 69.8, of which 12.68g of GaF_3 crystal is composed of ^{69}Ga , ^{71}Ga , and ^{19}F . The following statement is correct
- A · Mass of $^{69}GaF_3$ is about 40% in the crystal solid B · Mass of $^{71}GaF_3$ in crystal is 5.12 g
C · There are 5.8 mol of electrons in the crystal D · There are 3 mol of neutrons in $^{71}GaF_3$ in the crystal
- 1-7. A certain amount of hydrogen is burned in chlorine. After cooling, the resulting mixture is completely absorbed by 500mL of 0.6mol/L NaOH solution. The amount of NaClO in the solution is measured to be 0.05mol. The ratio between the amounts of hydrogen and chlorine used in the reaction is

A · 1:3 B · 3:2 C · 2:3 D · 3:4

1-8. There are four solutions of FeSO_4 , NH_4SCN , NaOH , and $\text{C}_6\text{H}_5\text{OH}$, and one reagent is used to distinguish them. The reagent(s) is/are

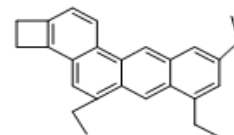
A · NaOH B · Potassium ferrocyanide C · Potassium ferricyanide D · FeCl_3

1-9. Sometimes glassware is not quite dry when doing experiments, but there is no drying equipment such as an oven. For convenience, you can perform the following operations to get glassware dried:

A · Wash with concentrated sulfuric acid B · Wash with sodium hydroxide solution
C · Add soda lime to the glassware D · Wash with diethyl ether

1-10. The picture below is an organic matter that resembles a puppy. The correct statement about the organic compound

A · Is an aromatic compound B · Cannot decolorize bromine solution
C · Is a liquid at RTP D · Has all the carbon atoms on the same plane



1-11. Ethanol gasoline is a kind of fuel made by adding an appropriate amount of ethanol to gasoline.

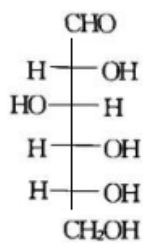
The correct statement(s) is/are

A · Ethanol gasoline is a mixture of various hydrocarbons B · The added ethanol is considered a renewable source of energy
C · Ethanol is commonly obtained by cracking industrially D · Ethanol can be obtained through fermentation of crops and various types of plant fiber

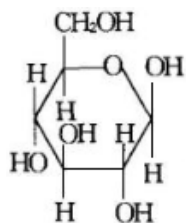
1-12.

The open chain structure of D-glucose is,

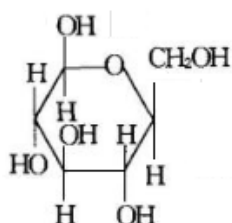
its ring structure may be



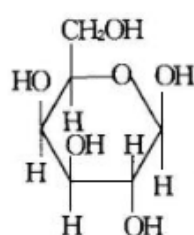
A ·



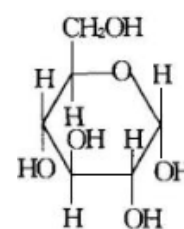
B ·



C ·



D ·



1-13. Determine which of the following compounds or ions are aromatic

A ·



B ·



C ·



D ·



1-14. The following ground state atoms having the correct electron configuration are

- A · [Ar]3d⁵4s¹ B · [Kr]3d⁷4s¹ C · [Kr]5d⁶5s² D · [Xe]4d⁸5s²

1-15. Add 7.5g of magnesium-aluminum alloy into a certain heated, concentrated nitric acid, the alloy is completely dissolved, and a total of 0.1 mol NO, 0.3 mol NO₂, and 0.05 mol N₂O₄ are produced. Add excess NaOH solution to the resultant solution to finally obtain a certain amount of white precipitate. The description about this process which is wrong

- A · 0.5 mol HNO₃ is oxidized B · 1.2 mol HNO₃ reacted
C · 0.7 mol of electrons are transferred D · 10.6 g of white precipitate is formed

Question 2 (10 points)

Write the corresponding ionic equation according to the information provided.

2-1. Cr₂O₇²⁻ is reduced to Cr³⁺ by NaHSO₃ in acidic solution.

2-2. At 80°C, pH = 2, NaClO is added to FeSO₄ to obtain disodium jarosite (Na₂Fe₆(SO₄)₄(OH)₁₂).

2-3. FeSO₄ is added dropwise to basic NaBH₄ solution, forming nano-iron powder, hydrogen gas and one more product.

2-4. Under standard condition, 0.007 mol Cl₂ is passed through 10 mL-1mol/L iron(II)bromide solution.

2-5. Solid Co(OH)₃ is added to Na₂SO₃ solution, dissolved by adding diluted sulfuric acid at the same time.

Question 3 (11 points)

Beryllium carbonate is burnt in air to obtain BeO, with a weight loss of 55.36%. The formula weight of the beryllium acetate obtained from the reaction between beryllium carbonate and hot ethanoic acid is 406.3, of which it contains 51.19% oxygen, 35.47% carbon, and 4.47% hydrogen. It is a complex molecule with high symmetry.

3-1. Calculate the molecular formula of beryllium carbonate.

3-2. Calculate the molecular formula of beryllium acetate.

3-3. Write down the chemical reaction equation for the reaction between beryllium carbonate and hot ethanoic acid.

3-4. Sketch the spatial structure of beryllium acetate.

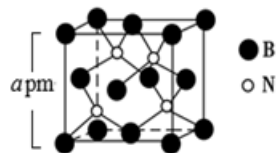
Question 4 (11 points)

Boron and its compounds have important industrial uses. Please answer the following questions:

4-1. Write down the hybridized orbitals and its spatial structure for B atom in BF_3 .

4-2. Ammonia borane is hydrolyzed catalytically, the B atoms have the same chemical environment in its product, $\text{B}_3\text{O}_6^{3-}$. Draw its structural formula.

Boron nitride (BN) is a highly regarded wear-resistant material, and its crystal unit cell is shown in the following figure:



4-3. In the BN crystal unit cell, what are (i) the packing order of B, (ii) the coordinates of N atoms?

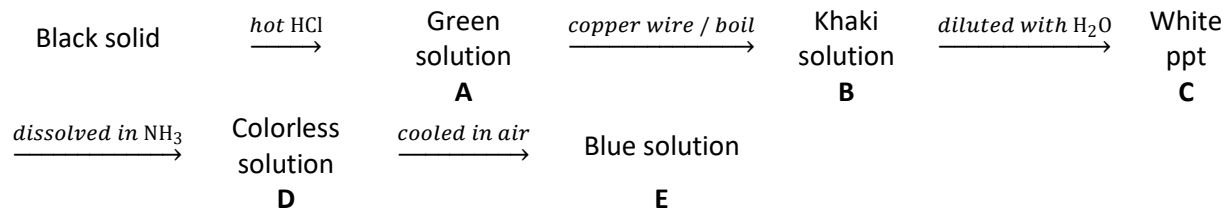
4-4. What is the shortest distance between a B and a N atom in the BN crystal unit cell?

4-5. Draw a BN crystal unit cell depicting the **100** plate projection.

Question 5 (5 points)

Black solid CuO can react in the following process, where **A** to **E** all contain Cu.

Determine the Cu containing chemical formula in each step from **A** to **E** process.

**Question 6 (5 points)**

Relative humidity is defined as the ratio between vapor pressure of water in air and that of saturated water in air.

At 0°C, it is given that $K^\theta = 4.68 \times 10^{-25}$ for $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{Na}_2\text{SO}_4(\text{s}) + 10\text{H}_2\text{O}(\text{g})$; and the vapor pressure of saturated water in air is 0.611 kPa.

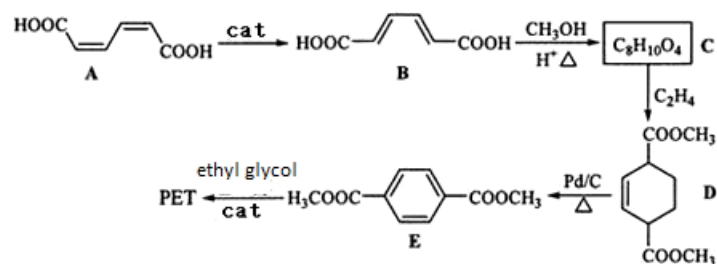
6-1. At 0°C, when $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ is decomposed (assume at equilibrium), calculate the water vapor pressure.

6-2. At 0°C, calculate the relative humidity at which $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ starts to erode when exposed in air.

Question 7 (11 points)

One of the reaction routes for the formation of polyethylene terephthalate (PET) is shown as follows:

7-1. Write down the chemical names for compounds **A** and **B**.



7-2. Write down (a) the reaction condition, (b) the reaction type for the step from **C** to **D**.

7-3. List the functional groups in **D**.

7-4. Write down the simplified structure of the isomer of **E** that meets the following condition.

- With two carboxyl groups;
- Two substituent aromatic compounds;
- Two substituent group at opposite ends (para/meta).

Question 8 (9 points)

The compound **A** has 8 carbon atoms in the main chain, the molecular formula is $\text{C}_{10}\text{H}_{16}\text{O}$; it can react with silver ammonia solution. Compound **A** can be hydrogenated by Ni catalyst to obtain compound **B** ($\text{C}_{10}\text{H}_{20}\text{O}$) and compound **C** ($\text{C}_{10}\text{H}_{22}\text{O}$); compound **A** reacts through O_3 and $\text{Zn}/\text{H}_2\text{O}$ to produce glyoxal (ethanedial), acetone, and compound **D**. Compound **D** is oxidized by silver ammonia solution to produce compound **E**, which has a molecular formula of $\text{C}_5\text{H}_8\text{O}_3$. Compound **E** reacts with $\text{I}_2\text{-NaOH}$ solution to produce iodoform and succinic acid (butanedioic acid).

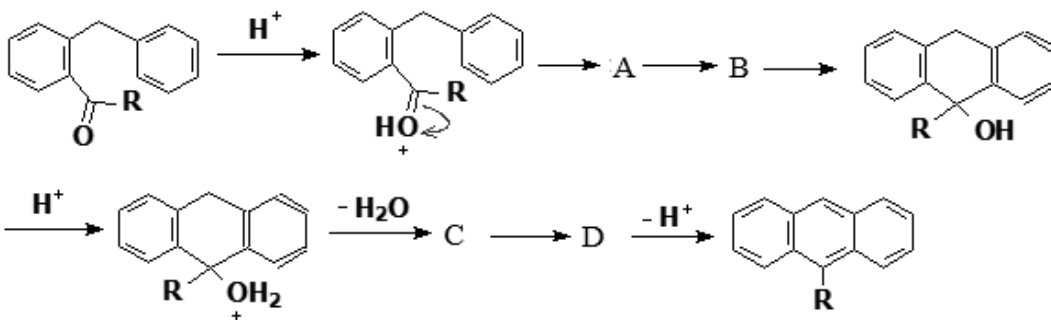
Deduce the structural formula from **A** to **E**, and write down the reaction step from **D** to **E**.

Question 9 (8 points)

An organic reaction involving several steps is depicted (right), where R denotes a particular functionality.



Write down the structural formula for compounds **A** to **D** in the following reaction steps using a curly arrow.



[End]