

National Examination for 2013 IChO
Taiwan (Chinese Taipei)
Round 1 (2 hours)

I. Multiple choices (3 pts each)

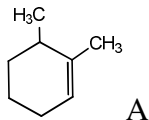
- Concentrated sulfuric acid was added to the following salts. Which one will NOT show a redox reaction?
(A) NaNO_2 (B) $\text{Na}_2\text{S}_2\text{O}_3$ (C) NaI (D) Na_3PO_4 (E) $\text{Na}_2\text{C}_2\text{O}_4$
- Element indium has molar mass of 114.8 g and atomic number of 49. There are two isotopes of indium, In-112 and In-115. What is the ratio of the nature abundance of these two isotopes?
(A) 6/94 (B) 25/75 (C) 50/50 (D) 75/25 (E) 94/6
- A colorless solution contains an ionic compound. By performing the following reactions, indentify the ionic compound.
Exp 1: Precipitation formed when small amount of sodium hydroxide were added to the solution. Continuous adding sodium hydroxide, the precipitates redissolved.
Exp 2: White precipitates formed when silver acetate was added to the solution.
(A) PbSO_4 (B) $\text{Ba}(\text{NO}_3)_2$ (C) CuSO_4 (D) AlCl_3 (E) FeI_2
- Which one of the following has the most negative reduction potential?
(A) F_2 (B) Ag (C) Na (D) Li^+ (E) C
- Coordination compound, $\text{Pt}(\text{NH}_3)_2(\text{C}_2\text{O}_4)$, is a chemotherapy compound for cancer. It is square planner. Which one of the following statement is correct regarding this compound?
(A) It has isomers.
(B) The oxidation number of the center metal is 0.
(C) The coordination number is 3.
(D) Its aqueous solution is conductive.
(E) It has two kinds of ligands.
- An element has electronic configuration of $[\text{Xe}]4f^{14}5d^76s^2$. This element belongs to which of the following groups?
(A) Inert gases (B) Transition metals (C) Alkaline earth metals
(D) Inner transition metals (E) Alkali metals

7. Which one of the following does NOT contain a planar molecule or ion?
- (A) NH_3 , H_2O_2 , N_2H_4
 (B) SF_4 , CO_3^{2-} , BF_3
 (C) ClF_3 , SO_4^{2-} , PCl_3
 (D) O_3 , PH_3 , CO_2
 (E) H_2O , H_2S , H_2Se
8. Which one of the following molecules has polarity?
- (A) CS_2 (B) SO_3 (C) CF_4 (D) IF_5 (E) SF_6
9. The dissociation of $\text{NO}_{2(g)}$ to $\text{NO}_{(g)}$ and $\text{O}_{2(g)}$ is second order reaction. At a fix temperature, the initial rate of the dissociation of $1.0 \times 10^{-4} \text{ M}$ of NO_2 is $1.0 \times 10^{-6} \text{ M}^{-1}\cdot\text{s}^{-1}$. How many seconds it will take to reduce $[\text{NO}_2]$ to the half of its initial concentration? (Assume the rate law does not change with concentration changes)
- (A) 50 (B) 100 (C) 150 (D) 200 (E) 250
10. Which of the following metal oxides cannot dissolve in strong alkali solution?
- (A) BeO (B) ZnO (C) Fe_2O_3 (D) Al_2O_3 (E) Cr_2O_3
11. Bismuth (Bi) is group 15 element and is four periods apart from nitrogen. How many electrons are filled in the *p* and *d* orbitals of each bismuth atom?
- (A) 53 (B) 57 (C) 59 (D) 61 (E) 63
12. The energy needed to break all the covalent bonds in propane is 4006 kJ/mol and 6356 kJ/mol for n-pentane. What is the average bond energy (kJ/mol) of C-C bond?
- (A) 347 (B) 368 (C) 386 (D) 414 (E) 432
13. A closed vessel contains hydrogen and nitrogen at mole ratio of 3:1. Under suitable catalyst, the gases react to form ammonium at a fix temperature. When reach equilibrium, the ratio of the square of the partial pressure of hydrogen and the partial pressure of nitrogen is 0.2. What is the K_p for the reaction $\text{N}_{2(g)} + 3 \text{H}_{2(g)} \rightarrow 2 \text{NH}_{3(g)}$?
- (A) 0.12 (B) 0.6 (C) 15 (D) 30 (E) 75
14. Which one of the molecule has different hybrid orbitals for the central atom from other molecules?
- (A) BF_3 (B) COCl_2 (C) IBr_3 (D) AlCl_3 (E) FNO_2
15. At 27°C and 0.82 atm, 300 mL of SO_2 completely breaches the color of KMnO_4 solution. What is the molarity of the KMnO_4 solution?
- (A) 0.02 (B) 0.05 (C) 0.04 (D) 0.03 (E) 0.06 M

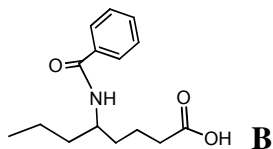
16. Which one of the following is not conjugate acid-base pair?
- (A) $\text{NH}_3, \text{NH}_4^+$
 (B) $\text{H}_2\text{PO}_4^-, \text{PO}_4^{3-}$
 (C) $\text{OH}^-, \text{H}_2\text{O}$
 (D) $\text{H}_2\text{CO}_3, \text{HCO}_3^-$
 (E) $\text{HSO}_4^-, \text{SO}_4^{2-}$
17. Traffic regulation in Taiwan states that "Those who exhales alcohol more than 0.25 mg/L should not drive". What is the equivalence in ppm?
- (A) 0.25 (B) 25 (C) 250 (D) 13.3 (E) 133 ppm °
18. Water dissociation reaction is endothermic and its dissociation constant, K_w , is 1.0×10^{-14} at 25°C. Which of the following statements is correct?
- (A) At 80°C, acid solution has $\text{pOH} + \text{pH} < 14$.
 (B) At 100°C, a solution at pH 7 is a neutral solution.
 (C) At 40°C, pure water has $\text{pOH} > 7$.
 (D) At 4°C, pure water has the smallest density and the lowest dissociation degree.
 (E) At 10°C, neutral solution has $\text{pH} < 7$.
19. Take 2.0 g of an acidic substance to make a 50 mL solution. Take 30 mL of the solution and titrated with 0.5 M of NaOH solution. At equivalent point, 40 mL of the NaOH solution were used. What is the acidic substance?
- (A) $\text{C}_6\text{H}_5\text{COOH}$ (B) HCOOH (C) H_2SO_4 (D) CH_3COOH (E) H_2CO_3
20. Consider a redox reaction: $\underline{a}\text{Fe}^{2+} + \text{MnO}_4^- + \underline{b}\text{H}^+ \rightarrow \underline{c}\text{Fe}^{3+} + \text{Mn}^{2+} + \underline{d}\text{H}_2\text{O}$; which of the following is correct?
- (A) $a = 4$ (b) $b = 6$ (C) $c = 5$ (D) $d = 2$ (E) $b = 5$
21. Phenolphthaleine, a common acid-base indicator, is a weak acid itself. It is colorless before dissociation and purplish-pink after dissociation. The color changing range is $\text{pH} = 8.0 \sim 9.6$. Which of the following is closest to its acid dissociation constant?
- (A) 3×10^{-5} (B) 9×10^{-8} (C) 6×10^{-10} (D) 6×10^{-12} (E) 5×10^{-15} °
22. Which of the following molecule uses same types of hybridization for carbons as those of 2,3-pentadiene?
- (A) 4-acetylenylcyclopentene (B) 2-pentyne (C) 1,3-cyclohexadiene
 (D) 4-oxopent-2-ene (E) cyclopropene

23. Which of the following compound has the highest solubility in water?
 (A) ethyl acetate (B) *n*-hexanol (C) acetic anhydride
 (D) *N,N*-dimethylformamide (E) cyclopentane

24. Which of the following nomenclature is correct for structure A?



- (A) 1,2-dimethylcyclohex-2-ene
 (B) 2,3-dimethylcyclohex-2-ene
 (C) 1,6-dimethylcyclohex-1-ene
 (D) 1,2-dimethylcyclohex-1-ene
 (E) 2,3-dimethylcyclohex-1-ene
25. What kind of functional groups in the molecular structure of B?



- (A) hydroxyl (B) ketone (C) amino (D) carboxyl (E) carbonyl
26. Which statement is correct for the following hydrocarbons ?
 (A) Cyclohexyne is very reactive at 30 °C and reacts with bromine at room temperature to give brominated compounds
 (B) There are four isomers for the molecular formula C₄H₈
 (C) There are two geometric isomers for 1,3-dimethylcyclohexane
 (D) 1-Pentene is easier to react with base than 1-pentyne
 (E) Reaction of cyclohexene with bromine results in the formation of 1,4-dibromocyclohexane

27. Which reaction or property of the following organic compounds is true?

- (A) When mixing with ZnCl₂ in acidic solution, 1-butanol turns the solution cloudy faster than 2-methyl-2-butanol
 (B) The acidity of 2-chlorobutanoid acid stronger than 3-chlorobutanoid acid
 (C) *n*-Butane is easier to undergo monochlorination than that of 2-methylbutane
 (D) The acidity of *p*-nitrobenzoic acid is stronger than *o*-nitrobenzoic acid
 (E) Fructose reacts with bromine produces gluconic acid

28. Which of the following compound reacts fastest with aqueous NaOH to provide substituted product

- (A) chloroethylene (B) chlorobenzene (C) chloroacetylene
(D) 1-chlorobutane (E) chlorocyclohexane

II: Multiple choice (There are more than one correct answer in each question) (5 pts each)

29. Regarding the reaction rates, which of the following statements are correct?

- (A) The reaction rate is slower for those with larger activation energy than the one with smaller activation energy.
(B) Addition of catalyst will alter the reaction path and lower the activation energy.
(C) Adding of catalyst will accelerate the forward reaction and decelerate the reverse reaction.
(D) Activation energy is dependent on the properties of the reactants and the solvents.
(E) Raise reaction temperature will increase the reaction rate, because it increases the collision frequency.

30. At 25°C, the saturated vapor pressure of toluene is approximately 30% of the benzene. They can be mixed to form an ideal solution that follows Raoult's law. Which of the following statements are correct?

- (A) Toluene has higher boiling point than benzene.
(B) Ideal solution indicates that the intermolecular forces can be neglected
(C) The mole fraction of benzene is higher in the vapor than in the liquid.
(D) The mole fraction of benzene in the vapor is not affected by the solution composition.
(E) The higher the mole fraction of benzene in a mixed solution, the lower the boiling point of the solution.

31. Which of the following statements are true?

- (A) Both graphite and diamond are insulators
(B) Graphene is a conductor
(C) Ionic compounds are insulators in solid state, but their aqueous solution is conductive.
(D) Molecular solids are insulators
(E) Molecular compounds are insulators in solid state, but their aqueous solution is conductive.

32. The table below shows the successive ionization energies I_n ($n = 1, \dots, 6$) of elements X and Y in kJ/mol.

	I_1	I_2	I_3	I_4	I_5	I_6
X	590	1146	4941	6485	8142	10519
Y	1086	2352	4619	6221	37820	47260

E and F are the oxides of X and Y respectively, such that the elements X and Y are present in their highest oxidation states.

E reacts with F to form a compound with the empirical formula

- (A) X_2YO_2
- (B) X_2YO_3
- (C) XY_2O_3
- (D) XYO_3
- (E) X_2YO_4

33. Regarding substances: Au, NH_4Br , HCl, NaCl, $C_6H_{12}O_6$, and CH_3OH , which of the following statements are correct?

- (A) There are 4 electrolytes.
- (B) There are metal bonds between Au atoms.
- (C) There are covalent bonds within HCl and CH_3OH molecules.
- (D) Liquid HCl is conducting via the movement of H^+ and Cl^- .
- (E) There are ionic bonds within NH_4Br and NaCl.

34. Charlie believes that MgO consists of Mg^+ and O^- ions. What properties of magnesium oxide may be utilized to convince Charlie that he is wrong?

- (A) Lattice enthalpy
- (B) Soluble in acid
- (C) Mass measured by magnetic balance.
- (D) Melton solution conducts electricity.
- (E) Melting point.

35. The saturate vapor pressure of water is 23.5 mmHg at $25^\circ C$. There is a pump filled with 0.18 g of water and has volume of 2.45 L. Which of the following changes do not affect the partial pressure of water in the pump?

- (A) Change the volume to three times the original
- (B) Change the volume to 1/2 of the original
- (C) Adding salts
- (D) Adding alcohols
- (E) Increasing the temperature to $27^\circ C$.

36. The following substances dissolve in water slightly. Which will have dramatic increase in the solubility upon the addition of sulfuric acid?
(A) Zn(OH)_2 (B) AgCl (C) CaCO_3 (D) $\text{Ca}_3(\text{PO}_4)_2$ (E) BaSO_4 °
37. The following statements are about colloidal solution, which are correct?
(A) After long standing, the colloidal solution will not precipitate. This indicates that the density of the colloidal particle is similar to the solution.
(B) Tyndall effect is due to the light scattering from colloidal particles.
(C) Because of Tyndall effect, all colloidal solutions are opaque.
(D) Upon the addition of small amount of electrolyte, colloidal particles deposit. It indicates the colloidal particles are charged.
(E) Colloidal solution may be filtered with filter paper to give a true solution.
38. Which of the following reactions are true for aromatic compounds?
(A) Reaction of benzene with bromine at room temperature generates bromobenzene
(B) Nitrobenzene is available via sulfuric acid-catalyzed reaction of benzene with nitric acid
(C) Nitrobenzene is easier to react with chloromethane in the presence of a catalytic amount of iron trichloride than toluene
(D) Benzoic acid is easier to react with acetyl chloride than phenol
(E) Benzyl alcohol is easier to react with aqueous HCl than 1-butanol
39. Which of the following statements are true about DNA ?
(A) Nucleotides are the building block unit of nucleic acids
(B) The chemical formula for deoxyribose is $\text{C}_5\text{H}_{10}\text{O}_5$
(C) DNA contains a carboxyl group
(D) There are intramolecular hydrogen-bonding in double helical DNA
(E) The sites of DNA are often determined by highly specific sequences of 5 types of nucleobases.
40. Which statements are correct for the following acids and bases?
(A) The acidity of $\text{C}_6\text{H}_{11}\text{NH}_3^+$ is stronger than that of $\text{C}_6\text{H}_5\text{NH}_3^+$
(B) The acidity of CH_3OH_2^+ is stronger than that of CH_3COOH
(C) The basicity of CH_3NH_2 is stronger than that of $\text{C}_6\text{H}_5\text{NH}_2$
(D) The acidity of $\text{C}_6\text{H}_5\text{COOH}$ is stronger than that of CH_3COOH
(E) The acidity of ethane is stronger than that of ethylene

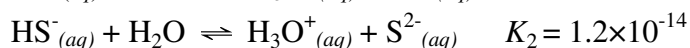
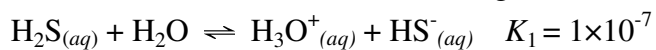
III. Problems

1. Dissolve 3.06 g sodium salt of a monoprotic weak acid (NaA) in 100 g of water, the resulting solution has pH value of 10, osmosis pressure of 9.78 atm, and density of 1.036 g/mL at 25 °C. Assume NaA completely dissociated in the solution, answer the following questions.

- (a) Calculate the mole of NaA (4 pts)
- (b) Calculate the molecular weight of HA (4 pts)
- (c) Calculate the concentration (in M) of HA in the solution. (2 pts)
- (d) Calculate acid dissociation constant K_a for HA (4 pts)

2. Sulfide, S^{2-} , forms precipitates with many heavy metal cations. Passing H_2S gas into aqueous solution gives S^{2-} . Under acidic conditions, the saturated H_2S concentration in water is 0.1 M.

It is known that dissolve H_2S in water gives the following reactions:



- (a) In an acid solution, pH = 2.0, what is the $[S^{2-}]$ (in M) at equilibrium in H_2S saturated solution? (4 pts)
- (b) Passing H_2S gas into a solution containing 0.1 M of $[Cd^{2+}]$ and 0.1 M of $[Tl^+]$ at pH = 2.0, which ion will precipitate until H_2S reach saturation? (4 pts)
$$CdS_{(s)} \rightarrow Cd^{2+} + S^{2-} \quad K_{sp} = 1 \times 10^{-27}$$
$$Tl_2S_{(s)} \rightarrow 2Tl^+ + S^{2-} \quad K_{sp} = 6 \times 10^{-22}$$
- (c) In order to separate the two ions, one can continuous passing H_2S gas into the solution until saturation, to have 99.9% of Cd^{2+} precipitated but not to precipitate Tl^+ . What should the $[H_3O^+]$ (in M) be maintained? (6 分)

3. Draw the chemical structure for products (a) to (f)

- (a) When ethylbenzene is treated with bromine under the U.V. light to give monobromination product (a)
- (b) Mixing of (a) with in hot NaOH(aq) affords a major product (b)
- (c) Treatment of (a) with NaOCH₂CH₃ in hot ethanol gives (c)
- (d) Reaction of (c) with KMnO₄(aq) at 0 °C under basic conditions afforded (d)
- (e) Reaction of (c) with aqueous hydrochloric acid produces (e)
- (f) Reaction of (b) with acetyl chloride yields (f)

4. In 7 test tubes with numbers from 1 to 7, there are dilute aqueous solutions of the following substances: CuSO_4 , AgNO_3 , NaCl , Na_2CO_3 , NaOH , HI , H_2SO_4 .

In the test tubes **X** and **Y**, there are dilute aqueous solutions of an unknown substance each.

The following reactions could be observed each time two of the nine solutions were mixed:

	1	2	3	4	5	6	7	X	Y
1	*	—	↓wy	↓bl	↑gas	—	↑gas	—	↓bl
2		*	↓w	—	—	—	—	—	—
3			*	—	↓y	↓b	—	↓y	↓w
4				*	↓b	↓bl	—	↓b	—
5					*	—	—	—	↓b
6						*	—	Pun. smell	↓bl
7							*	—	—
X								*	↓b
Y									*

Where ↓precipitate, color code on the right. y: yellow; b: brown; bl: blue; wy: yellowish white, w: white. ↑gas: gas evolved. —: no reaction.

(a) Write down the substance in each tubes. (2 pts each)

(b) What are substance X and Y? (1 pt each to both correct anion and cation)

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Key to Round 1

I. Multiple choices

1	2	3	4	5
D	A	D	C	E
6	7	8	9	10
B	A	D	B	C
11	12	13	14	15
B	A	E	C	A
16	17	18	19	20
B	E	A	D	C
21	22	23	24	25
C	A	D	E	E
26	27	28		
C	B	D		

II. Multiple choices (more than one correct answers, only complete set of correct answer get points)

			29	30
			BD	ACE
31	32	33	34	35
BCD	DE	BCE	ACE	AB
36	37	38	39	40
ACD	BD	BE	AD	BCD

III. Problems

1.

$\pi = cRT$; $9.78 = c \times 0.082 \times 298.15$; $c = 0.40 \text{ M}$; $[\text{NaA}] = 0.20 \text{ M}$

103.6 g of NaA solution is 100 mL, therefore, 0.020 mol NaA (4 pts)

NaA formula weight = $3.6/0.020 = 180 \text{ g/mol}$;

HA molecular weight = $180 - 22.0 = 158 \text{ g/mol}$ (4 pts)

(C) $\text{pH} = 10.0$, $[\text{HA}] = [\text{OH}^-] = 1.0 \times 10^{-4} \text{ M}$ (2 pts)

(D)

$$K_a = \frac{[\text{A}^-][\text{H}_3\text{O}^+]}{[\text{HA}]} = \frac{0.20 \times 1.0 \times 10^{-10}}{1.0 \times 10^{-4}} = 2.0 \times 10^{-7}$$
 (4 pts)

2.

(a) $K_1 \times K_2 = [\text{H}_3\text{O}^+]^2 [\text{S}^{2-}] / [\text{H}_2\text{S}] = 1.2 \times 10^{-21}$, $[\text{H}_2\text{S}] = 0.1 \text{ M}$, ($[\text{H}_2\text{S}] \gg [\text{HS}^-] \gg [\text{S}^{2-}]$)

$[\text{S}^{2-}] = 1.2 \times 10^{-22} / [\text{H}_3\text{O}^+]^2 = 1.2 \times 10^{-18} \text{ M}$

(b) for CdS: $1.2 \times 10^{-18} \times 0.1 = 1.2 \times 10^{-19} > K_{sp}$, will precipitate

for Ti_2S : $1.2 \times 10^{-18} \times 0.1 \times 0.1 = 1.2 \times 10^{-20} > K_{sp}$, will precipitate

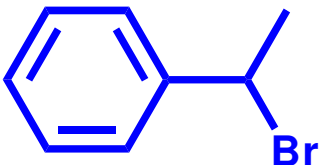
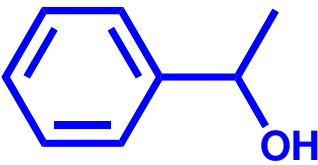
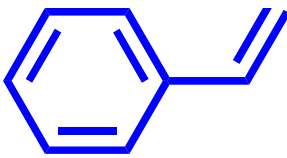
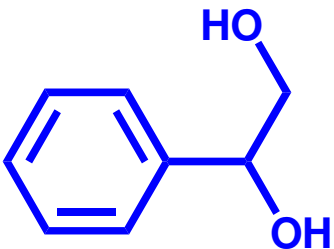
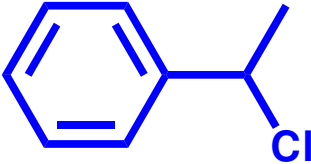
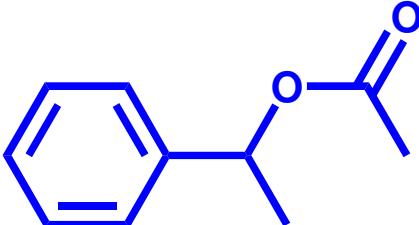
Ans: both ions will precipitate!

(c) to have 99.9% of Cd^{2+} precipitate, the $[\text{Cd}^{2+}]$ must be as low as $0.1 \text{ M} \times 0.1\% = 10^{-4} \text{ M}$

At this point, $[\text{S}^{2-}] = 1 \times 10^{-27} / 10^{-4} = 10^{-23} \text{ M}$

$[\text{H}_3\text{O}^+]^2 = 1.2 \times 10^{-22} / [\text{S}^{2-}] = 12$

$[\text{H}_3\text{O}^+] = 3.46 \text{ M}$

3.	(a) 1-bromoethylbenzene	(b) 1-(1-hydroxyethyl)benzene
	 1-bromoethylbenzene	 1-(1-hydroxyethyl)benzene
	(c) Styrene	(d) 1-(1,2-dihydroxyethyl)benzene
	 styrene	 1-(1,2-dihydroxyethyl)benzene
	(e) 1-(1-chloroethyl)benzene	(f) 1-(1-acetoxyethyl)benzene
	 1-(1-chloroethyl)benzene	 1-(1-acetoxyethyl)benzene

4.	1	2	3	4	5	6	7
	Na ₂ CO ₃	NaCl	AgNO ₃	CuSO ₄	HI	NaOH	H ₂ SO ₄
	X		Y				
	NH ₄ I		CuCl ₂				