

科目：普通化學 適用：應化所

編號：446

考生注意：

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## I. 單選題 (每題2分，共66分)

1. What ion seems to affect the levels of neurotransmitters, and thus is used in the treatment of depression or mania?

- [A]  $Mg^{2+}$  [B]  $Li^+$  [C]  $Na^+$  [D]  $Ca^{2+}$  [E]  $K^+$

2. Which of the following equations is not balanced?

- [A]  $4P_4 + 5S_8 \rightarrow 4P_4S_{10}$  [B]  $C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$  [C]  $4Al + 3O_2 \rightarrow 2Al_2O_3$   
[D]  $P_4 + 5O_2 \rightarrow P_4O_{10}$  [E]  $2KClO_3 \rightarrow 2KCl + \frac{3}{2}O_2$

3. Consider the gas phase reaction  $NO + (1/2)O_2 \rightleftharpoons NO_2$ , for which  $K = 1.5 \times 10^6$  at  $25^\circ C$ . Calculate  $K$  for the following reaction at  $25^\circ C$ :

- $2NO + O_2 \rightleftharpoons 2NO_2$   
[A]  $1.2 \times 10^3$  [B]  $1.5 \times 10^6$  [C]  $2.3 \times 10^{12}$   
[D]  $3.0 \times 10^6$  [E]  $7.5 \times 10^5$

4. Within the halogen family, as atomic number increases,

- [A] covalent atomic radius increases. [B] electronegativity increases.  
[C] ionic radius decreases. [D] melting point decreases.  
[E] none of these

5. Which of the following has the greatest bond strength?

- [A]  $O_2$  [B]  $O_2^+$  [C]  $CN$  [D]  $B_2$  [E]  $NO$

6. Which of the following statements about corrosion is false?

- [A] The oxidation of most metals by oxygen is spontaneous.  
[B] A car exposed to the elements will rust faster in the Midwest than in Arizona.  
[C] Most metals will develop a thin oxide coating, which protects their internal atoms from oxidation.  
[D] Patina is the layer of tarnish that gives silver a richer appearance.  
[E] All of these are true.

7. Which of the species below would you expect to show the least hydrogen bonding?

- [A]  $CH_4$  [B]  $H_2O$  [C] all the same [D]  $HF$  [E]  $NH_3$

8. We generally report a measurement by recording all of the certain digits plus \_\_\_\_\_ uncertain digit(s).

- [A] no [B] three [C] one [D] four [E] two

9. In cation-exchange resins, what ion replaces  $Ca^{2+}$  and  $Mg^{2+}$  in the hard water that is passed over the resin?

- [A]  $K^+$  [B]  $Ba^{2+}$  [C]  $Li^+$  [D]  $Na^+$  [E]  $H^+$

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10. A 3.31-g sample of lead nitrate,  $\text{Pb}(\text{NO}_3)_2$ , molar mass = 331 g/mol, is heated in an evacuated cylinder with a volume of 1.62 L. The salt decomposes when heated, according to the equation
- $$2\text{Pb}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{PbO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$$
- Assuming complete decomposition, what is the pressure in the cylinder after decomposition and cooling to a temperature of 300 K? Assume the  $\text{PbO}(\text{s})$  takes up negligible volume.
- [A] 0.380 atm [B] 0.228 atm [C] 0.0342 atm  
[D] 1.38 atm [E] none of these
11. Which metal, Al or Ni could reduce  $\text{Zn}^{2+}$  to  $\text{Zn}(\text{s})$  if placed in a  $\text{Zn}^{2+}(\text{aq})$  solution?
- [A] Cannot be determined. [B] Ni  $\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn} \quad E^\circ = -0.76 \text{ V}$   
[C] Neither Al nor Ni would work. [D] Al  $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al} \quad E^\circ = -1.66 \text{ V}$   
[E] Both Al and Ni would work.  $\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni} \quad E^\circ = -0.23 \text{ V}$
12. A weak acid, HF, is in solution with dissolved sodium fluoride, NaF. If HCl is added, which ion will react with the extra hydrogen ions from the HCl to keep the pH from changing?
- [A]  $\text{Na}^+$  [B]  $\text{OH}^-$  [C]  $\text{Na}^+$  [D]  $\text{F}^-$  [E] none of these
13. Which statement regarding water is true?
- [A] Liquid water is less dense than solid water.  
[B] Only covalent bonds are broken when ice melts.  
[C] Hydrogen bonds are stronger than covalent bonds.  
[D] Energy must be given off in order to break down the crystal lattice of ice to a liquid.  
[E] All of the statements (a-d) are false.
14. The number of a certain radioactive nuclide present in a sample decays from 160 to 20 in 30 minutes. What is the half-life of this radioactive species?
- [A] 15 minutes [B] 20 minutes [C] 10 minutes  
[D] 5 minutes [E] 30 minutes
15. Which of the following is *not* being considered as an energy source for the future?
- [A] carbon dioxide [B] shale oil [C] ethanol [D] methanol [E] seed oil
16. The monomers that make up a starch molecule are:
- I. optically active II. not optically active III. aldehydes IV. ketones  
and the polymer itself is formed primarily by V. addition VI. condensation
- [A] I, IV, VI [B] I, III, VI [C] I, III, V [D] II, IV, V [E] II, IV, VI
17. Select the correct molecular structure for  $\text{PCl}_4^+$  from the choices below:
- [A] pyramidal [B] tetrahedral [C] square planar [D] octahedral [E] none of these

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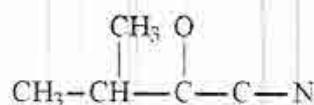
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18.  ${}^{40}_{20}\text{Ca}^{2+}$  has

- [A] 20 protons, 22 neutrons, and 18 electrons. [B] 20 protons, 20 neutrons, and 22 electrons.  
[C] 22 protons, 20 neutrons, and 20 electrons. [D] 20 protons, 20 neutrons, and 18 electrons.  
[E] 22 protons, 18 neutrons, and 18 electrons.

19. Complete the Lewis structure for the following molecule: This molecule has \_\_\_ sigma and \_\_\_ pi bonds.

- [A] 11, 5 [B] 6, 3 [C] 13, 2  
[D] 13, 3 [E] 4, 5

20. All of the following are weak acids *except*

- [A] HCN [B] HBr [C] HCNO [D] HF [E] HNO<sub>2</sub>

21. At room temperature, CsF is expected to be

- [A] a soft solid. [B] a brittle solid. [C] a conducting solid. [D] a gas. [E] a liquid.

22. Calculate the pOH of a 0.80 M solution of acetic acid ( $K_a = 1.8 \times 10^{-5}$ ).

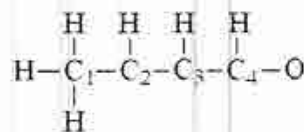
- [A] 11.58 [B] 4.74 [C] 2.42 [D] 9.25 [E] 7.87

23. Which of the following arrangements is in order of increasing size?

- [A]  $\text{Ga}^{3+} > \text{Ca}^{2+} > \text{S}^{2-} > \text{K}^+ > \text{Cl}^-$  [B]  $\text{Ga}^{3+} > \text{Ca}^{2+} > \text{K}^+ > \text{Cl}^- > \text{S}^{2-}$   
[C]  $\text{S}^{2-} > \text{Cl}^- > \text{K}^+ > \text{Ca}^{2+} > \text{Ga}^{3+}$  [D]  $\text{Ga}^{3+} > \text{Ca}^{2+} > \text{S}^{2-} > \text{Cl}^- > \text{K}^+$   
[E]  $\text{Ga}^{3+} > \text{S}^{2-} > \text{Ca}^{2+} > \text{Cl}^- > \text{K}^+$

24. Consider the compound crotonaldehyde, whose skeleton is the following: How many electrons must be shown in the Lewis structure of this molecule?

- [A] 32 [B] 12 [C] 18  
[D] 24 [E] 28

25. A balloon contains an anesthetic mixture of cyclopropane (cp) and oxygen (O<sub>2</sub>) at 170 torr and 570 torr, respectively. What is the ratio of the number of moles of cyclopropane to moles of oxygen,  $n_{\text{cp}} / n_{\text{O}_2} = ?$ 

- [A] 0.23 [B] 0.30 [C] 0.46 [D] 0.39 [E] 0.19

26. Elemental sulfur exists in two crystalline forms, rhombic and monoclinic. From the following data, calculate the equilibrium temperature at which monoclinic sulfur and rhombic sulfur are in equilibrium.

- |                | $\Delta H_f^\circ$ (kJ/mol) | $S^\circ$ (J/K·mol) |
|----------------|-----------------------------|---------------------|
| S (rhombic)    | 0                           | 31.88               |
| S (monoclinic) | 0.30                        | 32.55               |
- [A] -450 K [B] +450 K [C] 0 K [D] +210 K [E] -210 K

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27. The reaction  $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$  obeys the rate law  $-\frac{\Delta[\text{O}_2]}{\Delta t} = k_{\text{obsd}}[\text{NO}]^2[\text{O}_2]$ .

Which of the following mechanisms is consistent with the experimental rate law?

- [A]  $\text{O}_2 + \text{O}_2 \rightarrow \text{O}_2 + \text{O}_2^*$  (slow)      [B]  $2\text{NO} \rightleftharpoons \text{N}_2\text{O}_2$  (fast equilibrium)  
 $\text{O}_2 + \text{NO} \rightarrow \text{NO}_2 + \text{O}$  (fast)       $\text{N}_2\text{O}_2 \rightarrow \text{NO}_2 + \text{O}$  (slow)  
 $\text{O} + \text{NO} \rightarrow \text{NO}_2$  (fast)       $\text{NO} + \text{O} \rightarrow \text{NO}_2$  (fast)  
 [C]  $\text{NO} + \text{O}_2 \rightleftharpoons \text{NO}_3$  (fast equilibrium)      [D]  $\text{NO} + \text{NO} \rightarrow \text{N}_2\text{O}_2$  (slow)  
 $\text{NO}_3 + \text{NO} \rightarrow 2\text{NO}_2$  (slow)       $\text{N}_2\text{O}_2 + \text{O}_2 \rightarrow 2\text{NO}_2$  (fast)

[E] none of these

28. All of the following contribute to nitrogen-fixation except

- [A] lightning.      [B] the Haber process.      [C] the combustion process in car engines.  
 [D] bacteria on the roots of legumes.      [E] the Ostwald process.

29. Given the equation  $2\text{A(g)} \rightleftharpoons 2\text{B(g)} + \text{C(g)}$ . At a particular temperature,  $K = 1.6 \times 10^4$ .

Raising the pressure by lowering the volume of the container will

- [A] cause [A] to increase.      [B] cause [B] to increase.      [C] have no effect.  
 [D] cannot be determined.      [E] none of these.

30. What is the electron configuration of the Sc(I) ion?

- [A]  $[\text{Ar}]4s^2$       [B]  $[\text{Ar}]4s^13d^1$       [C]  $[\text{Ar}]3s^13d^1$   
 [D]  $[\text{Ar}]4s^14d^1$       [E]  $[\text{Ar}]3d^2$

31. Solid KF has a lattice energy of 804 kJ/mol and a heat of solution (in water) of -15 kJ/mol. RbF has a lattice energy of 768 kJ/mol and a heat of solution (in water) of -24 kJ/mol. Which salt forms stronger attractions with water?

- [A] KF, since it has a larger lattice energy  
 [B] RbF, since it has a more negative heat of hydration  
 [C] They form equally strong attractions with water, since they both have negative heats of mixing.  
 [D] RbF, since it has a smaller lattice energy  
 [E] KF, since it has a more negative heat of hydration

32. Consider pure water separated from an aqueous sugar solution by a semipermeable membrane, which allows water to pass freely but not sugar. After some time has passed, the concentration of sugar solution:

- [A] will be the same on both sides of the membrane.      [B] will have decreased.  
 [C] will not have changed.      [D] will have increased.  
 [E] might have increased or decreased depending on other factors.

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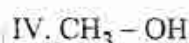
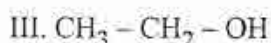
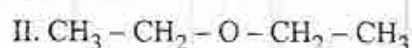
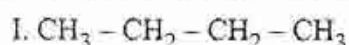
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33. Rank the following compounds according to increasing solubility in water.



[A] No order is correct.

[B]  $\text{I} < \text{III} < \text{IV} < \text{II}$ [C]  $\text{I} < \text{II} < \text{IV} < \text{III}$ [D]  $\text{I} < \text{II} < \text{III} < \text{IV}$ [E]  $\text{III} < \text{IV} < \text{II} < \text{I}$ 

## II. 簡答題 (共34分):

1. Write the formula for:

(a) sodium dichromate (1%)

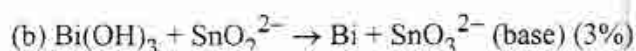
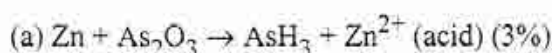
(b) iron (III) oxide (1%)

(c) dinitrogen trioxide (1%)

(d) aluminum hydroxide (1%)

(e) sulfurous acid (1%)

2. Balance each of the following equations.

3. Explain why  $\text{Al}_2(\text{SO}_4)_3$  produces an acidic solution when it is dissolved in water. (4%)4. What is the molarity of a  $\text{HNO}_3$  solution prepared by adding 250.0 mL of water to 350.0 mL of 12.3 M  $\text{HNO}_3$ ? Please show the calculating details. (4%)5. What is the operating definition of "paramagnetism"? (3%) Please use the molecular orbital model to explain that the  $\text{B}_2$  molecule is paramagnetic. (2%)

6. The hormone epinephrine is released in the human body during stress and increases the body's metabolic rate. Epinephrine, like many biochemical compounds, is composed of carbon, hydrogen, oxygen, and nitrogen. The percentage composition of the hormone is 56.8% C, 6.56% H, 28.4% O, and 8.28% N. Determine the empirical formula. Please show the calculating details. (6%)

7. Each orbital of the hydrogen atom is characterized by quantum numbers.

(a) What is the principal quantum number related to? (2%)

(b) A hydrogen 3s wave function has \_\_\_\_\_ (how many?) nodal planes (not counting  $r = 0$ )? (2%)