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二、考生應在答案卷上規定範圍內作答，且不得書寫任何與答案無關之文字、符號，違者該科不予計分。  
三、答案卷以每人一張為限，不得要求增補；試題與答案卷必須繳回，不得攜出試場。

\*可使用工程型計算機

**Multiple Choice**, choosing the one alternative that best completes the statement or answers the question (4 points each)

1. A correct name for  $\text{Fe}(\text{NO}_3)_2$  is \_\_\_\_\_.  
(A.) Iron nitrite      (B.) Ferrous nitrite      (C.) Ferric nitrite      (D.) Iron nitrate      (E.) Ferrous nitrate
2. A 0.8715 g sample of sorbic acid, a compound first obtained from the berries of a certain ash tree, is burned completely in oxygen to give 2.053 g of carbon dioxide and 0.5601 g of water. The empirical formula of sorbic acid is  
(A.)  $\text{CH}_2\text{O}$       (B.)  $\text{C}_3\text{H}_4\text{O}$       (C.)  $\text{CH}_4\text{O}_3$       (D.)  $\text{C}_3\text{H}_4\text{O}_2$       (E.)  $\text{CH}_4\text{O}_2$
3. Which compound has the atom with the highest oxidation number?  
(A.)  $\text{CaS}$       (B.)  $\text{Na}_3\text{N}$       (C.)  $\text{MgSO}_3$       (D.)  $\text{Al}(\text{NO}_2)_3$       (E.)  $\text{NaCl}$
4. Which of the following statements is false?  
(A.) The density of a gas is directly proportional to the external pressure.  
(B.) The density of helium gas is double that of hydrogen gas.  
(C.) The density of a gas is indirectly proportional to the temperature in Kelvin.  
(D.) All gases have the same density at STP.  
(E.) All the statements above are correct.
5. For which one of the following reactions is the value of  $\Delta H^\circ_{\text{rxn}}$  equal to  $\Delta H^\circ_f$  for the product?  
(A.)  $2\text{Ca}_{(s)} + \text{O}_{2(g)} \rightarrow 2\text{CaO}_{(s)}$   
(B.)  $\text{C}_2\text{H}_{2(g)} + \text{H}_{2(g)} \rightarrow \text{C}_2\text{H}_{4(g)}$   
(C.)  $2\text{C}_{(\text{graphite})} + \text{O}_{2(g)} \rightarrow 2\text{CO}_{(g)}$   
(D.)  $3\text{Mg}_{(s)} + \text{N}_{2(g)} \rightarrow \text{Mg}_3\text{N}_{2(s)}$   
(E.) None of these
6. A mole of yellow photons of wavelength 527 nm has \_\_\_\_\_ kJ of energy.  
(A.) 165  
(B.) 227  
(C.)  $4.56 \times 10^{-46}$   
(D.)  $6.05 \times 10^{-3}$   
(E.) 527
7. Using the following data reactions:  
 $\text{H}_{2(g)} + \text{Cl}_{2(g)} \rightarrow 2\text{HCl}_{(g)} \quad \Delta H^\circ = -184 \text{ kJ}$   
 $\text{H}_{2(g)} \rightarrow 2\text{H}_{(g)} \quad \Delta H^\circ = 432 \text{ kJ}$   
 $\text{Cl}_{2(g)} \rightarrow 2\text{Cl}_{(g)} \quad \Delta H^\circ = 239 \text{ kJ}$   
Calculate the energy of an H–Cl bond.  
(A.) 770 kJ      (B.) 856 kJ      (C.) 518 kJ      (D.) 487 kJ      (E.) 428 kJ

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

- (A.)  $B_2$             (B.)  $O_2^-$             (C.)  $CN^-$             (D.)  $O_2^+$             (E.)  $H_2$

9. A salt,  $MY$ , crystallizes in a body-centered cubic structure with a  $Y^-$  anion at each cube corner and an  $M^+$  cation at the cube center. Assuming that the  $Y^-$  anions touch each other and the  $M^+$  cation at the center, and that the radius of  $Y^-$  is 158 pm, what is the radius of  $M^+$ ?

- (A.) 65.4 pm            (B.) 116 pm            (C.) 79.0 pm            (D.) 41.1 pm            (E.) 105.3 pm

10. When 0.014 mol of a weak acid  $HA$  is dissolved in enough water to make 1.0 L of solution,  $[H^+]$  is  $1.8 \times 10^{-3}$  M. Calculate the freezing point of this solution. Assume that the molarity concentration is equal to the molality concentration, and assume ideal behavior.  $*K_{f(H_2O)}$  is  $1.86^\circ C \cdot kg/mol$ .

- (A.)  $-0.029^\circ C$             (B.)  $-0.026^\circ C$             (C.)  $-0.058^\circ C$             (D.)  $+0.029^\circ C$             (E.)  $+0.058^\circ C$

11. The kinetics of the reaction  $A + 3B \rightarrow C + 2D$  were studied and the following results obtained, where the rate law is:  $-\Delta[A]/\Delta t = k[A]^n[B]^m$ .

For a run where  $[A]_0 = 1.0 \times 10^{-3}$  M and  $[B]_0 = 5.0$  M, a plot of  $\ln[A]$  versus  $t$  was found to give a straight line with slope =  $-5.0 \times 10^{-2} s^{-1}$ .

For a run where  $[A]_0 = 1.0 \times 10^{-3}$  M and  $[B]_0 = 10.0$  M, a plot of  $\ln[A]$  versus  $t$  was found to give a straight line with slope =  $-7.1 \times 10^{-2} s^{-1}$ . Calculate the value of  $k$  (ignore units).

- (A.) 11            (B.) 10            (C.) 50            (D.) 1.1            (E.) 22

12. A possible mechanism for the overall reaction:  $Br_{2(g)} + 2NO_{(g)} \rightarrow 2NOBr_{(g)}$ :

$NO_{(g)} + Br_{2(g)} \rightleftharpoons NOBr_{2(g)}$  (fast; rate constant for forward reaction is  $k_1$  and  $k_{-1}$  for reverse reaction)

$NOBr_{2(g)} + NO_{(g)} \rightarrow 2NOBr_{2(g)}$  (slow; rate constant is  $k_2$ )

The rate law for formation of  $NOBr$  based on this mechanism is rate = \_\_\_\_\_.

- (A.)  $k_1[NO]^{1/2}$   
(B.)  $k_1[Br_2]^{1/2}$   
(C.)  $(k_2k_1/k_{-1})[NO]^2[Br_2]$   
(D.)  $(k_1/k_{-1})2[NO]^2$   
(E.)  $k_2[NOBr_2][NO]$

13. For the reaction  $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ ,  $K_p = 1.16$  at  $800^\circ C$ . If a 21.1 gram sample of  $CaCO_3$  is put into a 10.0 L container and heated to  $800^\circ C$ , what percent of the  $CaCO_3$  will react to reach equilibrium?

- (A.) 32.3%            (B.) 62.5%            (C.) 83.8%            (D.) 41.9%            (E.) 100.0%

14. What is the pH of a solution prepared by mixing 50.0 mL of 0.300 M  $HCl$  with 450.0 mL of 0.400 M  $HIO_3$ ? ( $K_a$  of  $HIO_3 = 0.16$ )

- (A.) 1.52            (B.) 0.80            (C.) 0.72            (D.) 0.89            (E.) 1.10

15. Consider the titration of 100.0 mL of 0.250 M aniline ( $K_b = 3.8 \times 10^{-10}$ ) with 0.500 M  $HCl$ . Calculate the pH of the solution at the stoichiometric point.

- (A.) -0.85            (B.) 8.70            (C.) 2.68            (D.) 11.62            (E.) 7.00

16. The  $K_f$  for the complex ion  $Ag(NH_3)_2^+$  is  $1.7 \times 10^7$ . The  $K_{sp}$  for  $AgCl$  is  $1.6 \times 10^{-10}$ . Calculate the molar solubility of  $AgCl$  in 1.0 M  $NH_3$ .

- (A.)  $5.2 \times 10^{-2}$  M            (B.)  $4.7 \times 10^{-2}$  M            (C.)  $2.9 \times 10^{-3}$  M            (D.)  $1.3 \times 10^{-2}$  M            (E.)  $3.5 \times 10^{-2}$  M

17. The equilibrium constant  $K$  for the dissociation reaction of a molecule  $X_2$



was measured as a function of temperature (in Kelvin). A graph of  $\ln K$  versus  $1/T$  for this reaction gives a straight line with a slope of  $-1.352 \times 10^4$  and an intercept of 15.59 K. The value of  $\Delta S$  for this dissociation reaction is:

- (A.) 1.875 J/K mol    (B.) 259.2 J/K mol    (C.) 32.4 J/K mol    (D.) 64.81 J/K mol    (E.) 129.6 J/K mol

18. An excess of finely divided iron is stirred up with a solution that contains  $Cu^{2+}$  ion, and the system is allowed to come to equilibrium. The solid materials are then filtered off and electrodes of solid copper and solid iron are inserted into the remaining solution. What is the value of the ratio  $[Fe^{2+}]/[Cu^{2+}]$  at  $25^\circ C$ ? The following standard reduction potentials apply:



- (A.) 1            (B.)  $1.3 \times 10^{26}$             (C.)  $2.5 \times 10^{26}$             (D.)  $4.4 \times 10^{-27}$             (E.)  $8.8 \times 10^{-27}$

19. Rubidium-87 decays by beta decay with a half-life of  $4.9 \times 10^{10}$  years. How many  $^{87}Rb$  atoms are in a moon rock sample that has a rubidium decay rate of 3500 disintegrations per hour?

- (A.)  $9.0 \times 10^{16}$  atoms  
(B.)  $4.3 \times 10^{-4}$  atoms  
(C.)  $2.2 \times 10^{18}$  atoms  
(D.)  $2.5 \times 10^{14}$  atoms  
(E.)  $2.6 \times 10^{15}$  atoms

20. What two oxidation states are more frequently observed in the first transition series than in the third?

- (A.) +3 and +7  
(B.) +2 and +3  
(C.) +2 and +7  
(D.) +5 and +6  
(E.) +2 and +5

21. Give the number of geometrical isomers for the octahedral compound  $[MA_2B_2C_2]$ , where A, B, and C represent ligands.

- (A.) 1            (B.) 2            (C.) 3            (D.) 5            (E.) 6

22. A particular first order reaction has a rate constant of  $1.35 \times 10^2 \text{ s}^{-1}$  at  $25.0^\circ C$ . What is the magnitude of  $k$  at  $75.0^\circ C$  if  $E_a = 55.3 \text{ kJ/mol}$ ?

- (A.)  $2.24 \times 10^4$             (B.)  $3.34 \times 10^3$             (C.) 433            (D.)  $1.05 \times 10^3$             (E.)  $2.49 \times 10^6$

23. For a particular reaction in a galvanic cell  $\Delta S^\circ$  is negative. Which of the following statements is true?

- (A.)  $E^\circ$  will increase with an increase in temperature.  
(B.)  $E^\circ$  will decrease with an increase in temperature.  
(C.)  $E^\circ$  will not change when the temperature increases.  
(D.)  $\Delta G^\circ > 0$  for all temperatures.  
(E.) None of these

24. Consider the reaction:  $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$

Given the following table of thermodynamic data at 298 K, the value of equilibrium constant for the reaction at 25 °C is \_\_\_\_\_.

Substance	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/K · mol)
$\text{NH}_3(\text{g})$	-46.19	192.5
$\text{HCl}(\text{g})$	-92.30	186.69
$\text{NH}_4\text{Cl}(\text{s})$	-314.4	94.6

- (A.) 150      (B.)  $9.3 \times 10^{15}$       (C.)  $8.4 \times 10^4$       (D.)  $1.1 \times 10^{-16}$       (E.)  $7.2 \times 10^{12}$

25. The molar enthalpy of vaporization of hexane ( $\text{C}_6\text{H}_{14}$ ) is 28.9 kJ/mol, and its normal boiling point is 68.73°C. What is the vapor pressure of hexane at 25°C?

- (A.) 4.44 torr      (B.) 117 torr      (C.) 241 torr      (D.) 759 torr      (E.) 171 torr