

※ 注意：請於試卷上「非選擇題作答區」標明題號並依序作答。

\*請在答案卷上標明題號依序作答，選擇題答案直接寫在答案卷上，例如：1. AB。

- $C = 3.00 \times 10^8 \text{ m/s}$ ;  $h = 6.626 \times 10^{-34} \text{ J-s}$ ;  $F = 96500 \text{ C/mol}$
- Gas constant:  $R = 8.314 \text{ J/mol-K} = 0.0821 \text{ L-atm/mol-K}$
- The periodic table: page 4

I. 選擇題 (60%, 選擇題每題答案可能 1 至多個, 全部選對始得題分 3 分)

1. A sulfuric acid solution,  $\text{H}_2\text{SO}_4$ , is 43% by mass and has a density of  $1.33 \text{ g/cm}^3$ . Calculate the molarity of  $\text{H}_2\text{SO}_4$  in this solution.  
(A) 4.4 M (B) 5.8 M (C) 18 M (D) None of the above
  2. Solubility rules predict precipitate formation for mixing 0.1 M aqueous solutions of  
(A) NaCl and  $\text{Hg}(\text{NO}_3)_2$  (B) HBr and  $\text{Ba}(\text{OH})_2$  (C)  $\text{H}_2\text{SO}_4$  and  $\text{Pb}(\text{NO}_3)_2$  (D)  $\text{AgNO}_3$  and  $\text{Na}_2\text{S}$
  3. The plots shown in the figure are the relative molecular speed distribution curves of two kinds of gases P and Q at  $25^\circ\text{C}$ . Which of the following statements are correct?  
(A) The root mean square speed of Q is greater than P.  
(B) The effusion rate of Q is greater than P.  
(C) The average kinetic energy of Q is greater than P.  
(D) The molar mass of Q is greater than P.
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4. The gas in a cylinder equipped with a piston (defined as the system) is warmed and absorbs 357 J of heat ( $q$ ). The expansion performs 123 J of work ( $w$ ) on the surroundings. Which of the followings is true? ( $\Delta E$ : change in internal energy)  
(A)  $q = +357 \text{ J}$  (B)  $w = +123 \text{ J}$  (C)  $\Delta E = +470 \text{ J}$  (D)  $\Delta H = 0 \text{ J}$
  5. In a coffee-cup calorimeter, 100.0 mL of 0.100 M  $\text{AgNO}_3$  and 100.0 mL of 0.100 M  $\text{HCl}$  are mixed to yield the following reaction:  $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$ . The two solutions were initially at  $23.40^\circ\text{C}$ , and the final temperature is  $24.20^\circ\text{C}$ . Calculate the heat of reaction in kJ/mol of  $\text{AgCl}$  formed. Assume that the combined solution has a mass of 200.0 g and a specific heat capacity of  $4.18 \text{ J}^\circ\text{C}^{-1}\text{g}^{-1}$ .  
(A) +33 kJ/mol (B) -33 kJ/mol (C) -67 kJ/mol (D) +67 kJ/mol (E) None of the above.
  6. For the following types of electromagnetic radiation: X-ray, ultraviolet (UV), visible, and infrared (IR), which of the following is correct?  
(A) Highest frequency: X-ray (B) Longest wavelength: visible  
(C) Greatest energy: UV (D) Lowest energy: IR
  7. How many orbitals have the quantum values of  $n = 5$  and  $l = 3$ ?  
(A) 2 (B) 3 (C) 5 (D) 7 (E) None of the above.
  8. Which of the following ranking is correct?  
(A) Ionic radius:  $\text{N}^{3-} > \text{O}^{2-} > \text{F}^-$  (B) First ionization energy:  $\text{Cl} > \text{S} > \text{Mg} > \text{Na}$   
(C) Atomic size:  $\text{Li} > \text{Na} > \text{K}$  (D) Bond polarity:  $\text{C-H} > \text{N-H} > \text{O-H}$
  9. Which of the following molecules would have dipole-dipole interaction?  
(A)  $\text{PCl}_5$  (B)  $\text{PH}_3$  (C)  $\text{SO}_3$  (D)  $\text{ClF}_3$

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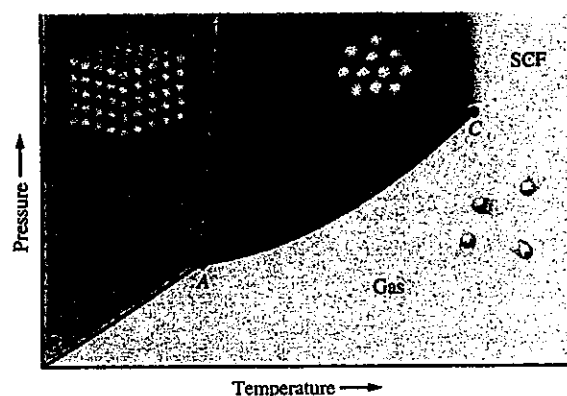
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10. For the following central atom (underlined), which one has the  $sp^2$  hybrid orbitals?

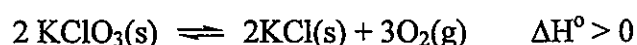
- (A) BeCl<sub>2</sub> (B) CH<sub>2</sub>O (C) SO<sub>2</sub> (D) H<sub>2</sub>S

11. According to the phase diagram shown, choose the correct answer.

- (A) Point A is the normal melting point.  
(B) Point C is the normal boiling point.  
(C) Curve AC is the vaporization curve.  
(D) SCF stands for super critical fluid.



12. Consider the following reaction at chemical equilibrium:



Which of the following will increase the equilibrium constant of the reaction?

- (A) Add some KClO<sub>3</sub>(s) to the system.  
(B) Add some catalyst to the system.  
(C) Increase the volume of the reaction mixture at constant temperature.  
(D) Raise the temperature of the system.

13. The decomposition of SO<sub>2</sub>Cl<sub>2</sub> is first order in SO<sub>2</sub>Cl<sub>2</sub> and has a rate constant of  $1.5 \times 10^{-4} \text{ s}^{-1}$  at a certain temperature. How long will it take for the concentration of SO<sub>2</sub>Cl<sub>2</sub> to decrease to 25% of its initial concentration?

- (A)  $1.5 \times 10^4 \text{ s}$  (B)  $3.0 \times 10^4 \text{ s}$  (C)  $4.6 \times 10^3 \text{ s}$  (D)  $9.2 \times 10^3 \text{ s}$  (E) None of the above

14. Consider the following reaction:  $\text{NO}_2(\text{g}) + \text{CO}(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{CO}_2(\text{g})$

The initial rate of the reaction is measured at several different concentrations of the reactants with the following results. If the initial concentrations of NO<sub>2</sub> and CO are 0.30 and 0.50 M respectively, what is the value of the initial rate of the reaction?

[NO <sub>2</sub> ] <sub>0</sub> (M)	[CO] <sub>0</sub> (M)	Initial rate (M/s)
0.10	0.10	0.0021
0.20	0.10	0.0082
0.20	0.20	0.0083
0.40	0.10	0.033

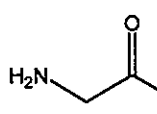
- (A) 0.019 M/s (B) 0.026 M/s (C) 0.032 M/s (D) 0.053 M/s (E) None of the above.

15. The solubility product constant ( $K_{sp}$ ) of an insoluble salt magnesium fluoride, MgF<sub>2</sub>, is  $4.0 \times 10^{-12}$ . Calculate the molar solubility of MgF<sub>2</sub> in a 1.0 M Mg(NO<sub>3</sub>)<sub>2</sub> solution.

- (A)  $1.0 \times 10^{-6} \text{ M}$  (B)  $2.0 \times 10^{-6} \text{ M}$  (C)  $1.0 \times 10^{-4} \text{ M}$  (D)  $1.6 \times 10^{-4} \text{ M}$  (E) None of the above

16. For the biopolymer, protein, choose the correct statement.

- (A) The building blocks of protein are  $\alpha$ -amino acids.  
(B) Protein is a kind of addition polymer.  
(C) The monomers are linked together by amide bonds.

(D) Glycine  is the simplest amino acid that is optically active.

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17. For the Haber process at 25°C,  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ ,  $\Delta H^\circ = -92 \text{ kJ}$  and  $\Delta S^\circ = -198 \text{ J/K}$ . Which of the following statements is correct?
- (A) This is an exothermic reaction.  
(B) The entropy of the system is increased.  
(C) The reaction is spontaneous under standard states and 25°C.  
(D) The reaction is very fast under standard states and 25°C.
18. If 22.44 mL of a 0.1652 M  $\text{KMnO}_4$  solution are required to titrate 25.00 mL of a  $\text{H}_2\text{O}_2$  solution, using the reaction:  $2\text{MnO}_4^- + 5\text{H}_2\text{O}_2 + 6\text{H}^+ \rightarrow 5\text{O}_2 + 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$ . Calculate the concentration of the  $\text{H}_2\text{O}_2$  solution.
- (A) 0.05931 M (B) 0.1483 M (C) 0.3707 M (D) None of the above.
19. Give the missing particle in the nuclear reaction:  ${}_{38}^{90}\text{Sr} \rightarrow ? + {}_{39}^{90}\text{Y}$
- (A)  $\frac{4}{2}\alpha$  (B)  $\frac{1}{0}n$  (C)  ${}_{+1}^0e$  (D)  ${}_{-1}^0e$
20. Which one of the following can be done to shorten the half-life of the radioactive decay of I-131?
- (A) Freeze it. (B) Heat it. (C) Oxidize to  $\text{I}_2$ .  
(D) Add certain catalyst (E) None of the above

II. 填充題 (30%，每題 3 分，僅需將答案填寫於答案卷上，無須計算過程)

21. A compound contains only nitrogen and hydrogen and is 87.4% nitrogen by mass. A gaseous sample of the compound has a density of 0.977 g/L at 710. torr and 100. °C. Give the molecular formula of the compound: (21).
22. Based on the **Molecular Orbital model**, give the electron configurations of the  $\text{C}_2$  molecule: (22).
23. For 0.10 M  $\text{NH}_3(\text{aq})$ , the pH value = (23).  $K_b = 1.0 \times 10^{-5}$ .
24. Blood is buffered by carbonic acid and the bicarbonate ion. Normal blood plasma is 0.0012 M in  $\text{H}_2\text{CO}_3$  and 0.024 M in  $\text{HCO}_3^-$ . Calculate the pH of blood plasma, pH = (24).  
The  $\text{pK}_{a1}$  for  $\text{H}_2\text{CO}_3$  at body temperature is 6.1, and  $\text{pK}_{a2}$  is 10.3.
25. Consider these reactions and their respective equilibrium constants:
- $$\text{NO}(\text{g}) + 1/2\text{Br}_2(\text{g}) \rightleftharpoons \text{NOBr}(\text{g}) \quad K = 5.3$$
- $$2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g}) \quad K = 2.1 \times 10^{30}$$
- Calculate the equilibrium constant K for the following reaction at that temperature,  $K =$  (25).
- $$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{NOBr}(\text{g})$$
26. Consider the reaction:  $\text{CO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$   $K = 2.26 \times 10^4$  at 25°C. For the reaction at 25°C under standard states,  $\Delta G^\circ =$  (26) kJ
27. For an electrochemical cell based on the reaction:  
 $\text{MnO}_4^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{Ag}(\text{s}) \rightarrow \text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 3\text{Ag}^+(\text{aq})$ ,  $E^\circ_{\text{cell}} = +0.88 \text{ V}$ .  
When  $[\text{MnO}_4^-] = 2.0 \text{ M}$  and  $[\text{Ag}^+] = 0.010 \text{ M}$ , calculate the  $E_{\text{cell}}$  for the reaction = (27) V.

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28~30. For the reaction,  $2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{NOCl}(\text{g})$ ,  
calculate the values of  $\Delta H^\circ$ ,  $\Delta S^\circ$ , and  $\Delta G^\circ$  at 298 K including the correct units from the following data.  
 $\Delta H^\circ =$  (28) ,  $\Delta S^\circ =$  (29) ,  $\Delta G^\circ =$  (30) .

	NO(g)	Cl <sub>2</sub> (g)	NOCl(g)
$\Delta H^\circ_f$ (kJ/mol)	90.3	—	51.7
$S^\circ$ (J/mol-K)	211	223	262

III. 計算問答題 (10%)

31. Answer the following questions concerning with the complex ion  $[\text{Co}(\text{en})_3]^{3+}$ .
- (A) Ethylenediamine (en) is a strong field ligand. Draw the structural formula of en.
- (B) What's the coordination number of central metal ion?
- (C) Draw the crystal-field energy-level diagrams, and show the placement of electrons for the complex.
- (D) Is the complex ion diamagnetic or paramagnetic?

1	2											13	14	15	16	17	18		
1A	2A											3A	4A	5A	6A	7A	8A		
1 H 1.008	2 He 4.003											3 Li 6.941	4 Be 9.012	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95		
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80		
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3		
55 Cs 132.9	56 Ba 137.3	57 *La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)		
87 Fr (223)	88 Ra (226)	89 *Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (268)	110 Ds (271)	111 Rg (280)	112 Uub	114 Uuq	116 Uuh	118 Uuo					

*Lanthanide series	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†Actinide series	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

試題隨卷繳回