

一、單選題 (50 題；每題 1.5 分)

- Which of the following pairs of compounds can be used to illustrate the law of multiple proportions?  
(A)  $\text{NH}_3$  and  $\text{NCl}_3$  (B)  $\text{ZnO}$  and  $\text{ZnCl}_2$  (C)  $\text{H}_2\text{O}$  and  $\text{HI}$  (D)  $\text{NO}$  and  $\text{NO}_2$  (E)  $\text{CH}_4$  and  $\text{CO}_2$
- Which of the following compounds has the same percent composition by mass as styrene?  
(A) acetylene,  $\text{C}_2\text{H}_2$  (B) benzene,  $\text{C}_6\text{H}_6$  (C) cyclobutadiene,  $\text{C}_4\text{H}_4$  (D)  $\alpha$ -ethyl naphthalene,  $\text{C}_{12}\text{H}_{12}$  (E) all of these
- $w\text{PCl}_5 + x\text{H}_2\text{O} \rightarrow y\text{POCl}_3 + z\text{HCl}$   
When the equation is properly balanced, what are the coefficients?  
(A)  $w = 1, x = 2, y = 2, z = 4$  (B)  $w = 2, x = 2, y = 2, z = 2$  (C)  $w = 2, x = 2, y = 2, z = 4$  (D)  $w = 1, x = 1, y = 1, z = 2$   
(E) none of these
- Consider five solutions that all have the same mass of solute in 100.0 mL of solution. Which has the highest concentration as measured in molarity?  
(A)  $\text{KCl}$  (B)  $\text{NaCl}$  (C)  $\text{Na}_2\text{SO}_4$  (D)  $\text{NaF}$  (E)  $\text{CaCl}_2$
- High concentrations of aqueous solutions of potassium hydroxide and copper(II) nitrate are mixed together. Which statement is correct?  
(A) both  $\text{KNO}_3$  and  $\text{Cu}(\text{OH})_2$  precipitate from solution (B) no precipitate forms (C)  $\text{Cu}(\text{OH})_2$  will precipitate from solution (D)  $\text{KNO}_3$  will precipitate from solution (E) no reaction will occur
- A solution contains the ions  $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ , and  $\text{Ni}^{2+}$ . Dilute solutions of  $\text{NaCl}$ ,  $\text{Na}_2\text{SO}_4$ , and  $\text{Na}_2\text{S}$  are available to separate the positive ions from each other. In order to effect separation, the solutions should be added in which order?  
(A)  $\text{Na}_2\text{SO}_4$ ,  $\text{NaCl}$ ,  $\text{Na}_2\text{S}$  (B)  $\text{Na}_2\text{SO}_4$ ,  $\text{Na}_2\text{S}$ ,  $\text{NaCl}$  (C)  $\text{Na}_2\text{S}$ ,  $\text{NaCl}$ ,  $\text{Na}_2\text{SO}_4$  (D)  $\text{NaCl}$ ,  $\text{Na}_2\text{S}$ ,  $\text{Na}_2\text{SO}_4$  (E)  $\text{NaCl}$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{Na}_2\text{S}$
- Which of the following reactions does *not* involve oxidation-reduction?  
(A)  $\text{CH}_4 + 2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2$  (B)  $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$  (C)  $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$  (D)  $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{Cl}_2 + 2\text{H}_2\text{O} + \text{MnCl}_2$  (E)  $\text{NaOH} + \text{HBr} \rightarrow \text{H}_2\text{O} + \text{NaBr}$
- A cylinder is fitted with a movable piston. The pressure inside the cylinder is  $P_i$  and the volume is  $V_i$ . What is the new pressure in the system when the piston decreases the volume of the cylinder by half?  
(A)  $(1/4)P_i$  (B)  $(1/2)P_i$  (C)  $2P_i$  (D)  $2V_iP_i$  (E)  $P_i^2$
- How many of the following gases at STP are less dense than air at STP?  
 $\text{NH}_3$ ,  $\text{He}$ ,  $\text{Kr}$ , and  $\text{F}_2$   
(A) 0 (B) 1 (C) 2 (D) 3 (E) 4
- The kinetic-molecular theory of gases does *not* assume that  
(A) gases are made up of tiny particles in constant chaotic motion (B) gas particles are very small compared to the average distance between the particles (C) gas particles collide with the walls of their container in elastic collisions (D) the average velocity of gas particles is directly proportional to the absolute temperature (E) all of these are correct
- Order the following according to increasing rate of effusion:  
 $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{CH}_4$   
(A)  $\text{Cl}_2 < \text{NO}_2 < \text{F}_2 < \text{NO} < \text{CH}_4$  (B)  $\text{Cl}_2 < \text{F}_2 < \text{NO}_2 < \text{CH}_4 < \text{NO}$  (C)  $\text{CH}_4 < \text{NO}_2 < \text{NO} < \text{F}_2 < \text{Cl}_2$  (D)  $\text{CH}_4 < \text{NO} < \text{F}_2 < \text{NO}_2 < \text{Cl}_2$  (E)  $\text{F}_2 < \text{NO} < \text{Cl}_2 < \text{NO}_2 < \text{CH}_4$
- A system at a state of chemical equilibrium is  
(A) microscopically dynamic and macroscopically static (B) microscopically dynamic and macroscopically dynamic (C) microscopically static and macroscopically static (D) microscopically static and macroscopically dynamic (E) none of these
- The value of the equilibrium constant  $K$  depends on:

I: the initial concentrations of the reactants

II: the initial concentrations of the products

III: the final concentrations of the reactants

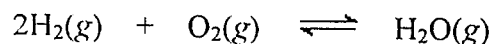
IV: the final concentrations of the products

(A) I and II only (B) II and III only (C) III and IV only (D) three of these (E) none of these

14. For a particular system at a particular temperature, there are \_\_\_ equilibrium constant(s) and \_\_\_ equilibrium position(s).

(A) an infinite number of, one (B) one, an infinite number of (C) one, one (D) an infinite number of, an infinite number of (E) none of these

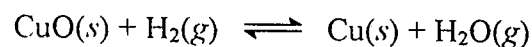
15. To increase the value of  $K$  for the exothermic reaction



we should

(A) increase the total pressure (B) decrease the total pressure (C) increase the temperature (D) decrease the temperature (E) two of these are necessary

16. When the substances in the equation below are at equilibrium at pressure  $P$  and temperature  $T$ , how can the equilibrium be shifted to favor the products?



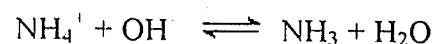
Change in enthalpy =  $-2.0$  kJ.

(A) decrease the temperature (B) add a catalyst (C) increase the pressure by adding an inert gas such as nitrogen (D) increase the pressure by means of a moving piston at constant temperature (E) allow some gas to escape at constant pressure and temperature

17. Which of the following is a conjugate acid-base pair?

(A)  $\text{HCl}/\text{OCl}_3^-$  (B)  $\text{H}_3\text{PO}_4/\text{PO}_4^{3-}$  (C)  $\text{NH}_4^+/\text{NH}_3$  (D)  $\text{H}_3\text{O}^+/\text{OH}^-$  (E)  $\text{Ca}^{2+}/\text{Ca}(\text{OH})_2$

18. What is the equilibrium constant for the following reaction?



(A)  $\frac{1}{K_b(\text{NH}_3)}$  (B)  $\frac{1}{K_a(\text{NH}_4^+)}$  (C)  $\frac{K_w}{K_a(\text{NH}_4^+)}$  (D)  $\frac{K_w}{K_b(\text{NH}_3)}$  (E)  $\frac{K_b(\text{NH}_3)}{K_w}$

19. Buffers in the human body

(A) help to maintain a constant blood pH (B) help to keep the body temperature constant (C) help change the blood plasma pH when foods are eaten (D) precipitate proteins so enzymes are inactive (E) none of these

20. Methyl orange is an indicator with a  $K_a$  of  $1 \times 10^{-4}$ . Its acid form,  $\text{HIn}$ , is red, while its base form,  $\text{In}^-$ , is yellow. At pH 6.0, the indicator will be

(A) red (B) orange (C) yellow (D) blue (E) not enough information

21. The solubility of  $\text{AgCl}$  in water is \_\_\_\_\_ the solubility of  $\text{AgCl}$  in strong acid at the same temperature.

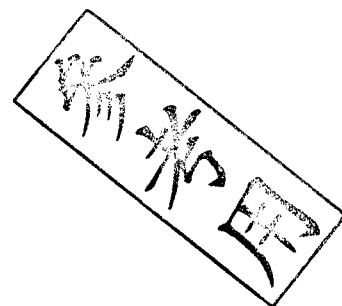
(A) greater than (B) less than (C) about the same as (D) cannot be determined (E) equal to

22. Which of the following statements is correct?

(A) the internal energy of a system increases when more work is done by the system than heat is flowing into the system (B) the internal energy of a system decreases when work is done on the system and heat is flowing into the system (C) the system does work on the surroundings when an ideal gas expands against a constant external pressure (D) all the statements are true (E) all the statements are false

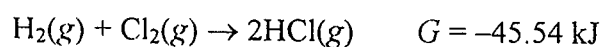
23. Which statement is true of a process in which 1 mol of a gas is expanded from state A to state B?

(A) when the gas expands from state A to state B, the surroundings are doing work on the system (B) the amount of work done in the process must be the same, regardless of the path (C) it is not possible to have more than one path for a change



of state (D) the final volume of the gas will depend on the path taken (E) the amount of heat released in the process will depend on the path taken

24. When a student performs an endothermic reaction in a calorimeter, how (if any) does the calculated value of  $\Delta H$  differ from the actual value if the heat exchanged with the calorimeter is not taken into account?
- (A)  $H_{\text{calc}}$  is more negative because the calorimeter always absorbs heat from the reaction (B)  $H_{\text{calc}}$  is less negative because the calorimeter absorbs heat from the reaction (C)  $H_{\text{calc}}$  is more positive because the reaction absorbs heat from the calorimeter (D)  $H_{\text{calc}}$  is less positive because the reaction absorbs heat from the calorimeter (E)  $H_{\text{calc}}$  equals the actual value because the calorimeter does not absorb heat
25. A mixture of hydrogen and chlorine remains unreacted until it is exposed to ultraviolet light from a burning magnesium strip. Then the following reaction occurs very rapidly.

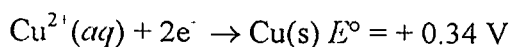
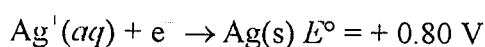


$$H = -44.12 \text{ kJ}$$

$$S = -4.76 \text{ J/K}$$

Select the statement below that best explains this behavior.

- (A) the reactants are thermodynamically more stable than the products (B) the reaction has a small equilibrium constant (C) the ultraviolet light raises the temperature of the system and makes the reaction more favorable (D) the negative value for  $\Delta S$  slows down the reaction (E) the reaction is spontaneous, but the reactants are kinetically stable
26. Choose the correct statement.
- (A) exothermic reactions are always spontaneous (B) free energy is independent of temperature (C) a reaction that exhibits a negative value of  $\Delta S$  cannot be spontaneous (D) at constant pressure and temperature, a decrease in free energy ensures an increase in the entropy of the system (E) none of these
27. The reaction,  $2\text{H}_2\text{O}(\text{g}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$ , has a positive value of  $\Delta G^\circ$ . Which of the following statements must be true?
- (A) the reaction is slow (B) the reaction will not occur. That is, when  $\text{H}_2\text{O}(\text{g})$  is introduced into a flask, no  $\text{O}_2$  or  $\text{H}_2$  will form even over a long period of time (C) the reaction is exothermic (D) the equilibrium lies far to the right (E) none of these is true
28. A strip of copper is placed in a 1 M solution of copper nitrate, and a strip of silver is placed in a 1 M solution of silver nitrate. The two metal strips are connected to a voltmeter by wires, and a salt bridge connects the solutions. The following standard reduction potentials apply:

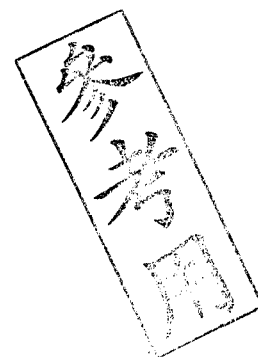


When the voltmeter is removed and the two electrodes are connected by a wire, which of the following does *not* take place?

- (A) electrons flow in the external circuit from the copper electrode to the silver electrode (B) the silver electrode increases in mass as the cell operates (C) there is a net general movement of silver ions through the salt bridge to the copper half-cell (D) negative ions pass through the salt bridge from the silver half-cell to the copper half-cell (E) some positive copper ions pass through the salt bridge from the copper half-cell to the silver half-cell
29. Why is aluminum protected from corrosion? (Note: The standard reduction potential for  $\text{Al}^{3+}$  is  $-1.66 \text{ V}$ .)
- (A) aluminum forms a protective oxide coating (B) the oxidation of aluminum is not a favored process, as seen by the standard reduction potential for  $\text{Al}^{3+}$  (C) oxygen and aluminum have no affinity for one another (D) at least two of these are correct (E) aluminum is not protected from corrosion
30. Which of the following is *not* determined by the principal quantum number,  $n$ , of the electron in a hydrogen atom?

- (A) the energy of the electron (B) the minimum wavelength of the light needed to remove the electron from the atom (C) the size of the corresponding atomic orbital(s) (D) the shape of the corresponding atomic orbital(s) (E) all of the above are determined by  $n$
31. Which of the following shows these molecules in order from most polar to least polar?  
 (A)  $\text{CH}_4 > \text{CF}_2\text{Cl}_2 > \text{CF}_2\text{H}_2 > \text{CCl}_4 > \text{CCl}_2\text{H}_2$  (B)  $\text{CH}_4 > \text{CF}_2\text{H}_2 > \text{CF}_2\text{Cl}_2 > \text{CCl}_4 > \text{CCl}_2\text{H}_2$   
 (C)  $\text{CF}_2\text{Cl}_2 > \text{CF}_2\text{H}_2 > \text{CCl}_2\text{H}_2 > \text{CH}_4 = \text{CCl}_4$  (D)  $\text{CF}_2\text{H}_2 > \text{CCl}_2\text{H}_2 > \text{CF}_2\text{Cl}_2 > \text{CH}_4 = \text{CCl}_4$   
 (E)  $\text{CF}_2\text{Cl}_2 > \text{CF}_2\text{H}_2 > \text{CCl}_4 > \text{CCl}_2\text{H}_2 > \text{CH}_4$
32. Choose the statement that best describes the  $\text{PbCl}_4$  molecule in the gas phase.  
 (A) the bond angles are all about  $109^\circ$  (B) the molecule is polar (C) the molecule has a dipole moment (D) the bonds are nonpolar (E) the molecule is polar with bond angles of about  $109^\circ$
33. As indicated by Lewis structures, which of the following species could probably *not* exist as a stable molecule?  
 (A)  $\text{NH}_3$  (B)  $\text{N}_2\text{H}_2$  (C)  $\text{N}_2\text{H}_4$  (D)  $\text{N}_2\text{H}_6$  (E)  $\text{N}_2\text{O}_4$
34. Select the correct molecular structure for  $\text{IF}_6^+$ .  
 (A) pyramidal (B) tetrahedral (C) square planar (D) octahedral (E) none of these
35. What is the hybridization of I in the molecule  $\text{ICl}_3$ ?  
 (A)  $sp$  (B)  $sp^2$  (C)  $sp^3$  (D)  $dsp^3$  (E)  $d^2sp^3$
36. Which statement about the thiocyanate ion,  $\text{SCN}^-$ , is true?  
 (A) its Lewis structure contains an unpaired electron (B) its shape is bent like that of  $\text{H}_2\text{O}$  (C) only one correct resonance structure can be drawn (D) there are more than two bonds in the ion (E) none of these
37. For which of the following is the half-life directly dependent on the concentration of the reactant?  
 (A) zero-order reaction (B) first-order reaction (C) second-order reaction (D) two of these (E) all of these
38. Identify the major attractive force in  $\text{CaF}_2$ .  
 (A) London dispersion forces (B) dipole-dipole interactions (C) hydrogen bonding (D) ionic bonding (E) none of these
39. Which statement about hydrogen bonding is true?  
 (A) hydrogen bonding is the intermolecular attractive forces between two hydrogen atoms in solution (B) the hydrogen-bonding capabilities of water molecules cause  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$  to be more soluble in water than is  $\text{CH}_3\text{OH}$  (C) hydrogen bonding of solvent molecules with a solute will not affect the solubility of the solute (D) hydrogen-bonding interactions between molecules are stronger than the covalent bonds within the molecule (E) hydrogen bonding arises from the dipole moment created by the unequal sharing of electrons in certain covalent bonds within a molecule
40. What compounds are useful in breathing apparatus and air supply packs?  
 (A) oxides (B) peroxides (C) superoxides (D) alkali metals (E) none of these
41. Order the following compounds from lowest to highest boiling point:  $\text{SnCl}_4$ ,  $\text{SnBr}_4$ ,  $\text{SnI}_4$ .  
 (A)  $\text{SnCl}_4$ ,  $\text{SnBr}_4$ ,  $\text{SnI}_4$  (B)  $\text{SnBr}_4$ ,  $\text{SnI}_4$ ,  $\text{SnCl}_4$  (C)  $\text{SnCl}_4$ ,  $\text{SnI}_4$ ,  $\text{SnBr}_4$  (D)  $\text{SnI}_4$ ,  $\text{SnBr}_4$ ,  $\text{SnCl}_4$  (E)  $\text{SnI}_4$ ,  $\text{SnCl}_4$ ,  $\text{SnBr}_4$
42. The deciding factor that makes HF a weak acid is that  
 (A) the enthalpy of hydration of  $\text{F}^-$  is negative (B) HF has a large bond energy (C) the entropy for hydration of  $\text{F}^-$  is a large negative value (D)  $\text{F}_2$  has a small bond energy (E)  $\text{F}^-$  has the largest ionization energy of all the halide ions
43. Which of the following statements is true about coordination complexes?  
 (A) the metal is a Lewis base and the ligands are Lewis acids (B) only complexes with coordination number 6 are found in nature (C) when the ligands approach a transition metal ion in an octahedral field, the  $d_{xz}$ ,  $d_{yz}$ , and  $d_{xy}$  atomic orbitals are affected the least by the ligands (D) none of these is true (E) all of these are true
44. \_\_\_\_ isomers and \_\_\_\_ isomers are classes of structural isomers.  
 (A) geometric, optical (B) coordination, geometric (C) linkage, geometric (D) coordination, linkage (E) geometric, linkage

45. The spectrochemical series is  
 $I < Br < Cl < F < OH^- < H_2O < NH_3 < en < NO_2^- < CN^-$   
 Which of the following complexes will absorb visible radiation of the highest energy (shortest wavelength)?  
 (A)  $[Co(H_2O)_6]^{3+}$  (B)  $[Co(I)_6]^{3-}$  (C)  $[Co(OH)_6]^{3-}$  (D)  $[Co(en)_3]^{3+}$  (E)  $[Co(NH_3)_6]^{3+}$
46. Which of the following is paramagnetic?  
 (A)  $[Zn(H_2O)_6]^{2+}$  (B)  $[Co(NH_3)_6]^{3+}$  (strong field) (C)  $[Cu(en)_3]^+$  (D)  $[Mn(en)_3]^{2+}$  (strong field) (E)  $[Fe(en)_3]^{2+}$  (strong field)
47. Consider the molecule *trans*-2-butene. Which statement is *true*?  
 (A) the molecule has two  $\pi$  bonds (B) there is free rotation around every bond in the molecule (C) *cis*-2-butene is its structural isomer (D) carbon #2 exhibits  $sp^2$  hybridization (E) none of these
48. Which of the following becomes more soluble in water upon the addition of NaOH?  
 (A) an amide (B) a carboxylic acid (C) an amine (D) an aromatic hydrocarbon (E) an alkane
49. When the following organic compound is oxidized, what is the major organic product?  
 $(CH_3)_2CHOH + KMnO_4 \rightarrow$   
 (A) 2-propanoic acid (B) 2-propanol (C) 2-propanone (D) 2-propanal (E) dimethylether
50. Aspirin is formed via a(n) \_\_\_\_\_ reaction.  
 (A) combustion (B) hydrogenation (C) addition (D) condensation (E) substitution



二、複選題 (10 題；每題 2.5 分)

51.  $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ,  $H = -1.37 \times 10^3 \text{ kJ}$   
 For the combustion of ethyl alcohol as described in the above equation, which of the following statements are *true*?  
 (A) the reaction is exothermic (B) the enthalpy change would be different if gaseous water were produced (C) the reaction is not an oxidation-reduction one (D) the products of the reaction occupy a larger volume than the reactants (E) it is a combustion reaction
52. Which of the following statements are *true*?  
 (A) an excited atom can return to its ground state by absorbing electromagnetic radiation (B) the energy of an atom is increased when electromagnetic radiation is emitted from it (C) the energy of electromagnetic radiation increases as its frequency increases (D) an electron in the  $n = 4$  state in the hydrogen atom can go to the  $n = 2$  state by emitting electromagnetic radiation at the appropriate frequency (E) The frequency and wavelength of electromagnetic radiation are inversely proportional to each other
53. Which of these molecules show resonances?  
 (A)  $BH_3$  (B)  $NO_2$  (C)  $SF_6$  (D)  $O_3$  (E)  $PCl_5$
54. Consider the molecular-orbital energy-level diagrams for  $O_2$  and  $NO$ . Which of the following are true?  
 (A) both molecules are paramagnetic (B) the bond strength of  $O_2$  is greater than the bond strength of  $NO$  (C)  $NO$  is an example of a homonuclear diatomic molecule (D) the ionization energy of  $NO$  is smaller than the ionization energy of  $NO^+$  (E) both are stable molecules
55. Which of the following statements are true?  
 (A) an orbital can accommodate at most two electrons (B) the electron density at a point is proportional to  $\psi^2$  at that point (C) the spin quantum number of an electron must be either  $+1/2$  or  $-1/2$  (D) a 2p orbital is more penetrating than a 2s; that is, it has a higher electron density near the nucleus and inside the charge cloud of a 1s orbital (E) in the usual order of filling, the 6s orbital is filled before the 4f orbital
56. Which statements about hydrogen are true?  
 (A) H has a lower ionization energy than He (B)  $H^-$  is smaller than H (C) H has a higher effective nuclear charge than He (D) H is always a metal (E) H does not have a second ionization energy

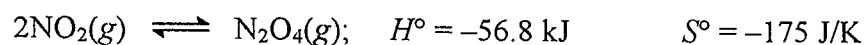
57. Which of the following ligands are capable of linkage isomerism?

- (A)  $\text{SCN}^-$  (B)  $\text{NO}_2^-$  (C)  $\text{OCN}^-$  (D)  $\text{NH}_3$  (E)  $\text{H}_2\text{O}$

58. To calculate the freezing point of an ideal dilute solution of a single, nondissociating solute in a solvent, the minimum information one must know is

- (A) the molality (of the solute) (B) the molality (of the solute) and the freezing-point-depression constant of the solvent (C) the freezing point of the pure solvent (D) the molecular weight of the solute (E) the weight of the solvent

59. Consider the reaction

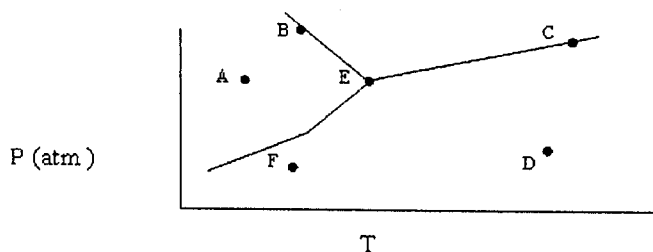


In a container (at 298 K),  $\text{N}_2\text{O}_4(g)$  and  $\text{NO}_2(g)$  are mixed with initial partial pressures of 2.4 atm and 0.42 atm, respectively. Which of the following statements are *false*?

- (A) some  $\text{N}_2\text{O}_4(g)$  will decompose into  $\text{NO}_2(g)$  (B) some  $\text{NO}_2(g)$  will dimerize to form  $\text{N}_2\text{O}_4(g)$  (C) the system is at equilibrium at these initial pressures (D) the final total pressure must be known to answer this question (E) none of these statements is *correct*

60. Based on the phase diagram shown below, which of the following statements are correct?

- (A) sublimation occurs at a point in the transformation that falls along a straight line from point A to point F (B) C and E represent points where the gas and liquid phases are in equilibrium (C)  $H_{\text{vap}}$  can be measured at point B (D) molecules at point D have a greater average kinetic energy than those at point F (E) the temperature at point E is called the critical temperature of the compound



注意：背面有試題