下列 40 題，皆為五選一選擇題，每題 2.5 分，答錯不倒扣分，共 100 分。

1. Which among the following represent a set of isotopes? Atomic nuclei containing:
   I. 20 protons and 20 neutrons.
   II. 21 protons and 19 neutrons.
   III. 22 neutrons and 18 protons.
   IV. 20 protons and 22 neutrons.
   V. 21 protons and 20 neutrons.
   (A) I, II, III
   (B) III, IV
   (C) I, V
   (D) I, IV, and II, V
   (E) No isotopes are indicated.

2. Rutherford's experiment was important because it showed that:
   (A) radioactive elements give off alpha particles.
   (B) gold foil can be made to be only a few atoms thick.
   (C) a zinc sulfide screen scintillates when struck by a charged particle.
   (D) the mass of the atom is uniformly distributed throughout the atom.
   (E) an atom is mostly empty space.

3. A substance, A_2B, has the composition by mass of 60% A and 40% B. What is the composition of AB_2 by mass?
   (A) 40% A, 60% B
   (B) 50% A, 50% B
   (C) 27% A, 73% B
   (D) 33% A, 67% B
   (E) none of these

4. Adipic acid contains 49.32% C, 43.84% O, and 6.85% H by mass. What is the empirical formula?
   (A) $C_3H_5O_2$
   (B) $C_3H_3O_4$
   (C) C_2HO_3
   (D) $C_2H_5O_4$
   (E) C_3HO_3

5. Which of the following are oxidation-reduction reactions?
   I. $PCl_3 + Cl_2 \rightarrow PCl_5$
   II. $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$
   III. $CO_2 + 2LiOH \rightarrow Li_2CO_3 + H_2O$
   IV. $FeCl_2 + 2NaOH \rightarrow Fe(OH)_2 + 2NaCl$
   (A) III
   (B) IV
   (C) I and II
   (D) I, II, and III
   (E) I, II, III, and IV

6. With what volume of 5.00 M HF will 4.34 g of calcium hydroxide react completely, according to the reaction: $2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O$
   (A) 11.7 mL
   (B) 117 mL
   (C) 586 mL
   (D) 23.4 mL
   (E) 42.7 mL

7. Which of the following is the best qualitative graph of P versus molar mass of a 1 g sample of different gases at constant volume and temperature?

(A) 　(B) 　(C) 　(D) 　(E) None of these

8. Consider the following gas samples:

Sample A	Sample B
$S_2(g)$	$O_2(g)$
$n = 1$ mol	$n = 2$ mol
$T = 800$ K	$T = 400$ K
$P = 0.20$ atm	$P = 0.40$ atm

(A) The volume of sample A is twice the volume of sample B.

(B) The average kinetic energy of the molecules in sample A is twice the average kinetic energy of the molecules in sample B.

(C) The fraction of molecules in sample A having a kinetic energy greater than some high fixed value is larger than the fraction of molecules in sample B having kinetic energies greater than that same high fixed value.

(D) The mean square velocity of molecules in sample A is twice as large as the mean square velocity of molecules in sample B.

(E) Assuming identical intermolecular forces in the two samples, sample A should be more nearly ideal than sample B.

9. Given the following reactions at 298 K and 1 atm, which of the statements is true?

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H_1$$
$$NO(g) + \tfrac{1}{2} O_2(g) \rightarrow NO_2(g) \qquad \Delta H_2$$
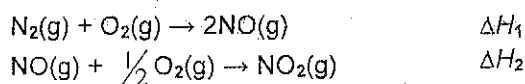
(A) ΔH_f° for $NO_2(g) = \Delta H_2$

(B) ΔH_f° for $NO(g) = \Delta H_1$

(C) $\Delta H_f^\circ = \Delta H_2$

(D) ΔH_f° for $NO_2(g) = \Delta H_2 + \dfrac{1}{2}\Delta H_1$

(E) $\Delta H_f^\circ = \Delta H_1$

10. Consider the reaction: $2ClF_3(g) + 2NH_3(g) \rightarrow N_2(g) + 6HF(g) + Cl_2(g)$

When calculating the ΔH_{rxn}, why is the ΔH_f° for N_2 not important?

(A) Because nitrogen is in its standard elemental state and no energy is needed for this product to exist.

(B) Because any element or compound in the gaseous state requires a negligible amount of energy to exist.

(C) Because the products are not included when calculating ΔH_{rxn}.

(D) Because nitrogen is in its elemental state and does not contribute to the reaction itself.

(E) Two of the above statements explain why N_2 is not important when calculating ΔH_{rxn}.

11. How many electrons in an atom can have the quantum numbers $n = 3$, $l = 2$?

(A) 2

(B) 5

(C) 10

(D) 18

(E) 6

12. Which of the following atoms would have the largest second ionization energy?
   (A) Mg
   (B) Cl
   (C) S
   (D) Ca
   (E) Na

13. Which of the following arrangements is in order of increasing size?
   (A) $Ga^{3+} > Ca^{2+} > K^+ > Cl^- > S^{2-}$
   (B) $Ga^{3+} < Ca^{2+} < K^+ < Cl^- < S^{2-}$
   (C) $Ga^{3+} > S^{2-} > Ca^{2+} > Cl^- > K^+$
   (D) $Ga^{3+} < Ca^{2+} < S^{2-} < Cl^- < K^+$
   (E) $Ga^{3+} > Ca^{2+} > S^{2-} > K^+ > Cl^-$

14. Choose the electron dot formula that most accurately describes the bonding in CS_2.
   (A) :S̈=C=S̈:
   (B) :C̈=S=S̈:
   (C) :S̈—C—S̈:
   (D) :S̈—C̈=S̈:
   (E) :S̈—C≡S:

15. Which of the nitrogen-containing molecules below is paramagnetic in its lowest energy state?
   (A) N_2
   (B) NO
   (C) NH_3
   (D) N_2H_4
   (E) CH_4

16. What is the bond order of He_2^+?
   (A) 0
   (B) 0.5
   (C) 1
   (D) 1.5
   (E) 2

17. Which one of the following decreases as the attractive intermolecular forces increases?
   (A) The heat of vaporization.
   (B) The normal boiling temperature.
   (C) The extent of deviations from the ideal gas law.
   (D) The sublimation temperature of a solid.
   (E) The vapor pressure of a liquid.

18. Sodium oxide crystallizes in a structure in which the O^{2-} ions are in a face-centered cubic lattice and the Na^+ ions are in tetrahedral holes. The number of Na^+ ions in the unit cell is:
   (A) 2
   (B) 4
   (C) 6
   (D) 8
   (E) none of these

19. When ethyl chloride, CH_3CH_2Cl, is dissolved in 1.0 M NaOH, it is converted into ethanol, CH_3CH_2OH, by the reaction $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$.
    At $25\,^\circ C$, the reaction is first order in CH_3CH_2Cl, and $k = 2.0 \times 10^{-3}\ s^{-1}$. If the activation constant $A = 3.4 \times 10^{14}\ s^{-1}$ and $E_a = 100.0$ kJ/mol, what will the rate constant be at $40\,^\circ C$?
    (A) $1.4 \times 10^{-2}\ s^{-1}$
    (B) $2.9 \times 10^{-4}\ s^{-1}$
    (C) $3.5 \times 10^{3}\ s^{-1}$
    (D) $3.9 \times 10^{-3}\ s^{-1}$
    (E) $1.0 \times 10^{-3}\ s^{-1}$

20. Calculate the osmotic pressure (in torr) of 6.00 L of an aqueous 0.855 M solution at $30\,^\circ C$, if the solute concerned is totally ionized into three ions.
    (A) 63.8 torr
    (B) 3.85×10^{-4} torr
    (C) 4.80×10^{-4} torr
    (D) 1.62×10^{-4} torr
    (E) 5.39×10^{-4} torr

21. The vapor pressure of water at $90\,^\circ C$ is 0.692 atm. What is the vapor pressure of a solution made by dissolving 1.92 moles of CsF(s) in 1.0 kg of water? Assume that Raoult's law applies.
    (A) 0.669 atm
    (B) 0.740 atm
    (C) 0.647 atm
    (D) 0.692 atm
    (E) 0.798 atm

22. Consider a reaction of the type a A → Products in which the rate law is found to be rate = $k[A]^3$. If the first half life of the reaction is 40 seconds, what is the time for the second half life?
    (A) 10 seconds
    (B) 20 seconds
    (C) 80 seconds
    (D) 160 seconds
    (E) 320 seconds

23. For the reaction $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$, $K_p = 1.16$ at $800\,^\circ C$. If 43.7 grams of $CaCO_3$ in a 10-L flask were heated to $800\,^\circ C$, what percent of the $CaCO_3$ will react to reach equilibrium?
    (A) 15.6%
    (B) 30.2%
    (C) 40.5%
    (D) 81.0%
    (E) 100%

24. At $-80\,^\circ C$, $K = 4.66 \times 10^{-8}$ for the reaction, $N_2O_4(g) \rightleftharpoons 2NO_2(g)$. We introduce 0.038 mole of N_2O_4 into a 1.0-L vessel at $-80\,^\circ C$ and let equilibrium be established. The total pressure in the system at equilibrium will be:
    (A) 0.25 atm
    (B) 0.60 atm
    (C) 1.12 atm
    (D) 0.04 atm
    (E) 0.80 atm

25. For stepwise dissociation of H_3PO_4, which of the following is not a conjugate acid base pair?
    (A) HPO_4^{2-} and PO_4^{3-}
    (B) H_3PO_4 and $H_2PO_4^-$
    (C) $H_2PO_4^-$ and HPO_4^{2-}
    (D) $H_2PO_4^-$ and PO_4^{3-}
    (E) H_3O^+ and H_2O

26. Calculate the pH of a 4.7×10^{-3} M KOH solution.
    (A) 2.33
    (B) 12.67
    (C) 11.67
    (D) 1.33
    (E) 10.67

27. In the titration of a weak acid HA with 0.100 M NaOH, the stoichiometric point is known to occur at a pH value of approximately 11. Which of the following indicators would be best to use to mark the endpoint of this titration?
    (A) an indicator with $K_a = 10$
    (B) an indicator with $K_a = 10^{-3}$
    (C) an indicator with $K_a = 10^{-4}$
    (D) an indicator with $K_a = 10^{-1}$
    (E) an indicator with $K_a = 10^{-2}$

28. The solubility of $CaSO_4$ in water at $0\,^{\circ}C$ is 1.15 g/L. The value of the solubility product is
    (A) 8.45×10^{-3}
    (B) 1.15×10^{-3}
    (C) 9.19×10^{-2}
    (D) 7.14×10^{-5}
    (E) 6.32×10^{-4}

29. Given the following data, calculate the normal boiling point in $^{\circ}C$ for formic acid (HCOOH).

	ΔH_f (kJ/mol)	ΔS (J/mol K)
HCOOH(l)	-410	130.0
HCOOH(g)	-363	251.3

    (A) 0.39
    (B) 387
    (C) 660
    (D) 279
    (E) 114

30. Which of the following will increase K?　$CO_2(g) + 2H_2O(g) \rightleftharpoons CH_4(g) + 2O_2(g)$,　$\Delta H^{\circ} = 803$ kJ
    (A) decrease number of moles of methane
    (B) increase volume of system
    (C) increase the temperature of system
    (D) all of the above
    (E) none of the above

31. A fuel cell designed to react grain alcohol with oxygen has the following net reaction: $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$.　The maximum work one mole of alcohol can yield by this process is 1320 kJ. What is the theoretical maximum voltage this cell can achieve?
    (A) 0.760 V
    (B) 1.14 V
    (C) 2.01 V
    (D) 2.28 V
    (E) 3.37 V

32. Gold (atomic mass = 197) is plated from a solution of $HAuCl_4$, it deposits on the cathode. Calculate the time it takes to deposit 0.48 gram of gold, passing a current of 0.10 amperes.
    (A) 41 minutes
    (B) 2.0 hours
    (C) 39 minutes
    (D) 13.2 minutes
    (E) 1.5 hours

33. Which group contains two elements that exhibit +2 and +4 oxidation states?

    (A) Group 1A
    (B) Group 3A
    (C) Group 4A
    (D) Group 5A
    (E) Group 7A

34. With which of the following elements does silicon form the strongest bonds?

    (A) Si
    (B) C
    (C) H
    (D) O
    (E) B

35. The complex FeL_6^{2+} (L = neutral ligand) is diamagnetic. What is the number of d electrons on Fe^{2+} ion?

    (A) 4
    (B) 5
    (C) 6
    (D) 7
    (E) 8

36. Which of the following is a d^7 ion?

    (A) Co(II)
    (B) Cu(II)
    (C) Mn(II)
    (D) Ru(II)
    (E) Cr(II)

37. Which of the following pairs is incorrect?

    (A) octane = C_9H_{20}
    (B) heptane = C_7H_{16}
    (C) pentane = C_5H_{12}
    (D) propane = C_3H_8
    (E) mathane = CH_4

38. Which of the following functional groups does not contain a doubly bonded oxygen?

    (A) aldehyde
    (B) ester
    (C) ketene
    (D) carboxylic acid
    (E) ether

39. Four identical 1.0-L container contains the gases He, Cl_2, CH_4, C_2H_4, each at $0\ ^\circ C$ and 1 atm pressure. For which gas do the molecules have the smallest average kinetic energy?

    (A) He
    (B) Cl_2
    (C) CH_4
    (D) C_2H_4
    (E) all gases the same

40. In the lab, you mix two solutions of the same temperature and the temperature of the resulting solution decreases. Which of the following is true?

    (A) The chemical reaction is releasing energy.
    (B) The energy released is equal to $s \times m \times T$.
    (C) The chemical reaction is absorbing energy.
    (D) The chemical reaction is exothermic.
    (E) all of the above.