題目分選擇題及問答題兩部份，考試時間 90 分鐘。

第一部份　**單一選擇題** 共 30 題，每題 2 分，合計 60 分，答錯不倒扣。

1. Four identical 1.0-L flasks contain the gases He, Cl_2, CH_4, and NH_3, each at 0°C and 1 atm pressure. For which gas do the molecules have the highest average velocity? (atomic mass: H, 1.01; He, 4.00; C, 12.00; N, 14.01; Cl, 35.45)
   (A) He　　　　(B) Cl_2　　　　(C) CH_4　　　　(D) NH_3　　　　(E) They have the same average velocity

2. Which of the following species is *not* amphoteric?
   (A) $H_2PO_4^-$　　　(B) HPO_4^{2-}　　　(C) HSO_4^-　　　(D) H_2O　　　(E) All of these are amphoteric.

3. In a solution prepared by adding excess $PbI_2(s)$ ($K_{sp} = 1.4 \times 10^{-8}$) to water, $[I^-]$ at equilibrium is
   (A) 1.5×10^{-3} mol/L.　　　　(B) 2.4×10^{-3} mol/L.　　　　(C) 1.2×10^{-4} mol/L.
   (D) 8.4×10^{-5} mol/L.　　　　(E) 3.0×10^{-3} mol/L.

4. At 25°C, the following heats of reaction are known:
   $$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O \qquad \Delta H = -2600 \text{ kJ}$$
   $$C + O_2 \longrightarrow CO_2 \qquad \Delta H = -394 \text{ kJ}$$
   $$2H_2 + O_2 \longrightarrow 2H_2O \qquad \Delta H = -572 \text{ kJ}$$
   At the same temperature, calculate ΔH for the following reaction:　$2C + H_2 \longrightarrow C_2H_2 \qquad \Delta H = ?$
   (A) 226 kJ　　　(B) -226 kJ　　　(C) 2422 kJ　　　(D) -2422kJ　　　(E) none of these

5. For the vaporization of water at 1.00 atm, $\Delta H = 43.54$ kJ/mol at 298 K and $\Delta H = 40.68$ kJ/mol at 373 K. The constant-pressure heat capacity for $H_2O(l)$ is 75.3 J/mol · K. Calculate the constant-pressure heat capacity for $H_2O(g)$.
   (A) 20.8 J/ mol · K　　　　(B) 37.2 J/ mol · K　　　　(C) 2790 J/ mol · K
   (D) 75.3 J/ mol · K　　　　(E) none of these

6. Consider the following reduction potentials:
   $$Cu^{2+} + 2e^- \longrightarrow Cu \qquad E° = +0.34 \text{ V}$$
   $$Pb^{2+} + 2e^- \longrightarrow Pb \qquad E° = -0.13 \text{ V}$$
   For a galvanic cell employing the Cu, Cu^{2+} and Pb, Pb^{2+} couples, calculate the maximum amount of work that would accompany the reaction of 1 mol of lead under standard conditions. (Faraday's constant $F = 96485$ C/mol)
   (A) –40.5 kJ　　　　　(B) –45.3 kJ　　　　　(C) –90.7 kJ
   (D) No work can be done. The system is at equilibrium.　　　　(E) none of these

7. How many seconds would it take to deposit 21.40 g of Ag (atomic mass = 107.87) from a solution of $AgNO_3$ using a current of 10.00 amp?
   (A) 9649 s　　　(B) 4825 s　　　(C) 3828 s　　　(D) 1914 s　　　(E) none of these

8. How many f orbitals have the value $n = 3$?
   (A) 0　　　(B) 1　　　(C) 3　　　(D) 5　　　(E) 7

9. What is the electron configuration of Cr^{3+}? (atomic number = 24)
   (A) [Ar] $4s^2 3d^1$　(B) [Ar] $4s^1 3d^2$　(C) [Ar] $3d^3$　(D) [Ar] $4s^2 3d^4$　(E) none of these

10. Which of the following molecules has a nonzero dipole moment?
    (A) CCl_4　　　(B) SiF_4　　　(C) CS_2　　　(D) SO_3　　　(E) PBr_3

11. Which of the following has the largest radius?
    (A) O^{2-}　　　(B) F^-　　　(C) Ne　　　(D) Na^+　　　(E) Mg^{2+}

12. Using the bond energies in the following table to estimate the heat of combustion for 1 mol of acetylene:

$$C_2H_2(g) + 5/2 O_2(g) \longrightarrow 2CO_2(g) + H_2O(g)$$
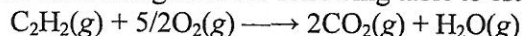
Bond	C≡C	C—H	O=O	C=O	O—H
Bond Energy (kJ/mol)	839	413	495	799	467

(A) 1228 kJ　　　　(B) −1228 kJ　　　　(C) −447 kJ　　　　(D) +447 kJ　　　　(E) +365 kJ

13. Which of the following is diamagnetic?
(A) O_2^-　　　　(B) F_2^+　　　　(C) B_2　　　　(D) NO　　　　(E) O_2^{2-}

14. Vibrational transitions in molecules typically require energies that correspond to the _____ region of the electromagnetic spectrum.
(A) UV　　　　(B) IR　　　　(C) microwave　　　(D) visible　　　(E) X-ray

15. The following data were obtained for the reaction of NO with O_2. Concentrations are in molecules/cm^3 and rates are in molecules/cm$^3 \cdot$ s.

| $[NO]_0$	$[O_2]_0$	Initial Rate
1×10^{18}	1×10^{18}	2.0×10^{16}
2×10^{18}	1×10^{18}	8.0×10^{16}
3×10^{18}	1×10^{18}	18.0×10^{16}
1×10^{18}	2×10^{18}	4.0×10^{16}
1×10^{18}	3×10^{18}	6.0×10^{16}

Which of the following is the correct rate law?
(A) Rate = $k[NO][O_2]$　　　　(B) Rate = $k[NO][O_2]^2$　　　　(C) Rate = $k[NO]^2[O_2]$
(D) Rate = $k[NO]^2$　　　　(E) Rate = $k[NO]^2[O_2]^2$

16. Which of the following is the correct order of boiling points for $NaNO_3$, CH_3OH, C_2H_6, and Ne?
(A) Ne < CH_3OH < C_2H_6 < $NaNO_3$　　　　(B) $NaNO_3$ < CH_3OH < C_2H_6 < Ne
(C) Ne < C_2H_6 < $NaNO_3$ < CH_3OH　　　　(D) Ne < C_2H_6 < CH_3OH < $NaNO_3$
(E) C_2H_6 < Ne < CH_3OH < $NaNO_3$

17. A material is made from Al, Ga, and As. The mole fractions of these elements are 0.23, 0.26, and 0.51, respectively. This material would be
(A) a metallic conductor because Al is present.　　　(B) an insulator.
(C) an n-type semiconductor.　　　(D) a p-type semiconductor.　　　(E) none of these

18. When a nonvolatile solute is added to a volatile solvent, the solution vapor pressure _____, the boiling point _____, the freezing point _____, and the osmotic pressure across a semipermeable membrane _____.
(A) decreases, increases, decreases, decreases　　　(B) increases, increases, decreases, increases
(C) increases, decreases, increases, decreases　　　(D) decreases, decreases, increases, decreases
(E) decreases, increases, decreases, increases

19. At a given temperature, you have a mixture of benzene (P_{vap} = 745 torr) and toluene (P_{vap} = 290 torr). The mole fraction of benzene in the solution is 0.590. Assuming ideal behavior, calculate the mole fraction of toluene in the vapor above the solution.
(A) 0.213　　　　(B) 0.778　　　　(C) 0.641　　　　(D) 0.355　　　　(E) 0.590

20. Given the graph below, what is the boiling point of carbon tetrachloride at standard pressure?
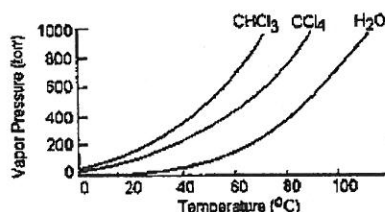
(A) 60°C　　　　(B) 34°C　　　　(C) 98°C　　　　(D) 77°C　　　　(E) none of above

21. Which of the following oxides is amphoteric?
    (A) BeO　　　　　(B) MgO　　　　　(C) CaO　　　　　(D) SrO　　　　　(E) BaO

22. Choose the correct molecular structure for XeF_4.
    (A) trigonal bipyramidal　　　　(B) trigonal planar　　　　(C) tetrahedral
    (D) octahedral　　　　　　　　　(E) square planar

23. Which of the metal ions in the following complex ions has a d^5 electron configuration?
    (A) $[V(H_2O)_6]^{2+}$　　(B) $[Ni(NH_3)_6]^{3+}$　　(C) $[Co(CN)_6]^{3-}$　　(D) $[FeCl_6]^{4-}$　　(E) $[Fe(CN)_6]^{3-}$

24. Specify the number of unpaired electrons in CoF_6^{3-} (F^- ion is a weak field ligand). (atomic number = 27)
    (A) 0　　　　　(B) 1　　　　　(C) 2　　　　　(D) 4　　　　　(E) 5

25. Which of the following transition metals is a component of vitamin B_{12}?
    (A) cobalt　　　　(B) chromium　　　　(C) manganese　　　　(D) copper　　　　(E) zinc

26. The Cs-131 nuclide has a half-life of 30 years. After 120 years, about 3 g remain. The original mass of the Cs-131 sample is closest to
    (A) 30 g　　　　(B) 40 g　　　　(C) 50 g　　　　(D) 60 g　　　　(E) 70 g

27. How many isomers are there with the formula C_3H_4? Include both structural and geometric isomers.
    (A) 1　　　　　(B) 2　　　　　(C) 3　　　　　(D) 4　　　　　(E) 5

28. Which of the following statements are true about starch?
    I.　　monomers are fructose and glucose.
    II.　　monomer is glucose.
    III.　the main carbohydrate reservoir in plants.
    IV.　the main carbohydrate reservoir in animals.
    V.　　an addition polymer.
    VI.　a condensation polymer.
    (A) I, III, IV, V　　(B) II, IV, VI　　(C) II, III, VI　　(D) I, III, V　　(E) I, IV, V

29. Which of the following is optically active (that is, chiral)?
    (A) diethylamine　　　　　(B) difluoromethane　　　　(C) 2-bromopropan
    (D) 2-chloropentane　　　　(E) 1-chlorohexane

30. Consider the polymer drawn below:
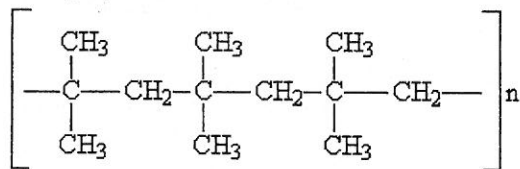
    What monomer(s) is (are) needed to produce the above polymer?
    (A) $CH_3CH = CHCH_3$　　　　　　　　(B) $CH_2 = C(CH_3)_2$　　　　　(C) CO and $CH_2 = CH_2$
    (D) $CH_2 = CH_2$ and $CH_3CH = CH_2$　　(E) none of the above

第二部份　　問答題　　第 31 至 36 題為簡答題，37 題為閱讀申論題，合計 40 分。

31. Balance the following reaction:

____As_2O_3 + ____HNO_3 + ____H_2O ⟶ ____H_3AsO_4 + ____NO 　　　　　(5 分)

32. Which substances of the followings have a standard enthalpy of formation ΔH°_f value of zero:

$Br_2(l)$, $C(s)$ (graphite), $C(s)$ (diamond), $H^+(aq)$, $H_2O(l)$, $Hg(l)$, $O_3(g)$, $NaCl(s)$ 　　(5 分)

33. Arrange the following in order of increasing entropy, S°:

$Hg(l)$, 　　$Hg(s)$, 　　$C_6H_6(l)$, 　　$CH_3OH(l)$, 　　$CO(g)$ 　　　　　(5 分)

34. Given the equilibrium $COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$ 　　$\Delta H = +108$ kJ

Suggest *three* possible ways to decrease the concentration of Cl_2. 　　　　　(6 分)

35. Give the full name (in English or Chinese) for the following abbreviations:

(a) DNA 　　　(b) NMR 　　　(c) LED 　　　　　(6 分)

36. The structure of sodium chloride can be described in terms of a cubic closest packed array of Cl^- ions with Na^+ ions in all the octahedral sites. Write the density of NaCl in the form of the formula weigth of NaCl (W_{NaCl}) and the radii of Na^+ and Cl^- (r_{Na^+} and r_{Cl^-}). 　　　　　(3 分)

37. 下面是從 2010 年 11 月 22 日美國化學會的雜誌 C&EN 摘錄一段關於氫鍵的報導請仔細閱讀，依文章所述將目前教科書上與 IUPAC 建議新的氫鍵定義作說明，並比較兩者不同處。(本題請用中文作答)　　(10 分)

Hydrogen Bond Reformulation

Textbooks currently define a hydrogen bond as a weak electrostatic interaction that forms between a lone pair of electrons on an electronegative atom and a hydrogen atom bonded to another strongly electronegative atom, typically oxygen, nitrogen, or fluorine. But that definition belies a rich assortment of chemical associations that have come to be called hydrogen bonds in the 90 years since Wendell M. Latimer and Worth H. Rodebush first coined the term. To address the disparity between definition and practice, a task group of the International Union of Pure & Applied Chemistry (IUPAC) has proposed a new, broader definition of hydrogen bonds.

The proposed definition is intentionally expansive: "The hydrogen bond is an attractive interaction between a hydrogen atom from a molecule or a molecular fragment X–H in which X is more electronegative than H, and an atom or a group of atoms in the same or a different molecule, in which there is evidence of bond formation." The proposal, available at media.iupac.org/reports/provisional/abstract11/arunan_310311.html, goes on to outline experimental and theoretical criteria that can be used as evidence for the presence of a hydrogen bond.