1 atm = 101325 Pa; \ h = 6.626 \times 10^{-34} \text{ J s}; \ c = 3.0 \times 10^8 \text{ m/s}; \ \ln 10 = 2.3;
\ m_e = 9.1 \times 10^{-31} \text{ kg}; \ R = 0.0821 \text{ atm l/K/mol} = 8.314 \text{ J/K/mol}; \ \ R_H = 2.18 \times 10^{-18} \text{ J}

單選題（每題 2 分）:

1. Which one of the following is most likely to be an ionic compound?
   (A) KF \quad (B) \text{CCl}_4 \quad (C) \text{CS}_2 \quad (D) \text{CO}_2 \quad (E) \text{ICl}

2. What is the energy in joules of one photon of microwave radiation with a wavelength 0.122 m?
   (A) 2.70 \times 10^{-40} \text{ J} \quad (B) 5.43 \times 10^{-33} \text{ J} \quad (C) 1.63 \times 10^{-24} \text{ J}
   (D) 4.07 \times 10^{-10} \text{ J} \quad (E) 2.46 \times 10^{-22} \text{ J}

3. What is the formal charge on sulfur in the best Lewis structure for the SCN⁻ (thiocyanate) ion?
   (A) +2 \quad (B) -2 \quad (C) +1 \quad (D) -1 \quad (E) 0

4. Which of the following solids would have the highest melting point?
   (A) NaF \quad (B) NaCl \quad (C) NaBr \quad (D) NaI \quad (E) H₂O

5. The total number of bonding electrons in a molecule of formaldehyde (H₂CO) is
   (A) 3 \quad (B) 4 \quad (C) 6 \quad (D) 8 \quad (E) 18

6. How many orbitals are allowed in a subshell if the angular momentum quantum number for electrons in that subshell is 3?
   (A) 1 \quad (B) 3 \quad (C) 5 \quad (D) 7 \quad (E) 9

7. Which of these species would you expect to have the lowest standard entropy (S°)?
   (A) CH₄(g) \quad (B) HF(g) \quad (C) NH₃(g) \quad (D) H₂O(g) \quad (E) C₃H₆

8. The Lewis structure for CS₂ is:
   (A) \begin{array}{c}
   \text{C} \\
   \cdots \cdots \\
   \text{S} \end{array} \quad (B) \begin{array}{c}
   \cdots \cdots \\
   \text{S} \quad \begin{array}{c}
   \text{C} \\
   \cdots \cdots \\
   \text{S} \end{array}
   \end{array} \quad (C) \begin{array}{c}
   \text{S} = \text{C} = \cdots \\
   \end{array} \quad (D) \begin{array}{c}
   \cdots \cdots \\
   \text{S} = \text{C} = \begin{array}{c}
   \text{S} \\
   \cdots \cdots \\
   \end{array}
   \end{array}
   \quad (E) \text{None of these}

9. Which one of the following reactions would you expect to have the lowest ΔS°?
   (A) CH₄(g) + 2O₂(g) → CO₂(g) + 2H₂O(g) \quad (B) C₂H₂(g) + \frac{5}{2}O₂(g) → 2CO₂(g) + H₂O(g)
   (C) C₂H₄(g) + O₂(g) → 2CO₂(g) + 2H₂O(g) \quad (D) C₂H₆(g) + \frac{7}{2}O₂(g) → 2CO₂(g) + 3H₂O(g)

10. Aluminum forms a layer of aluminum oxide when exposed to air which protects the bulk metal from further corrosion. \ 4 \text{Al(s)} + 3 \text{O}_2(g) → 2 \text{Al}_2\text{O}_3(s)
Using the thermodynamic data provided below, calculate ΔS° for this reaction.

<table>
<thead>
<tr>
<th>\text{S°(J/K-mol)}</th>
</tr>
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<tbody>
<tr>
<td>Al(s)</td>
</tr>
<tr>
<td>O₂(g)</td>
</tr>
<tr>
<td>Al₂O₃(s)</td>
</tr>
</tbody>
</table>

(A) 182.3 J/K-mol \quad (B) 131.5 J/K-mol \quad (C) -182.3 J/K-mol \quad (D) -626.2 J/K-mol \quad (E) -802.9 J/K-mol
11. HI has a normal boiling point of $-35.4^\circ$C, and its $\Delta H_{\text{vap}}$ is 21.16 kJ/mol. Calculate the molar entropy of vaporization ($\Delta S_{\text{vap}}$).
(A) 598 J/K·mol  (B) 68.6 J/K·mol  (C) 75.2 J/K·mol  (D) 0.068 J/K·mol  (E) 89.0 J/K·mol

12. Estimate the enthalpy change for the reaction $2\text{CO} + \text{O}_2 \rightarrow 2 \text{CO}_2$ given the following bond energies.
$\text{BE(C=O)} = 1074 \text{kJ/mol}$  $\text{BE(O=O)} = 499 \text{kJ/mol}$  $\text{BE(C=O)} = 802 \text{kJ/mol}$
(A) $+249 \text{kJ/mol}$  (B) $+744 \text{kJ/mol}$  (C) $+561 \text{kJ/mol}$  (D) $-561 \text{kJ/mol}$  (E) $-744 \text{kJ/mol}$

13. A negative sign for $\Delta G$ indicates that, at constant $T$ and $P$,
(A) the reaction is exothermic.  (B) the reaction is endothermic.  (C) the reaction is fast.
(D) the reaction is spontaneous.  (E) $\Delta S$ must be $> 0$.

14. The equilibrium constant at 700 K for the reaction $\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g)$ is $K_p = 1.0 \times 10^{-4}$. Calculate the value of $\Delta G^\circ$ for the reaction under these conditions.
(A) $-33 \text{kJ/mol}$  (B) $-54 \text{kJ/mol}$  (C) $54 \text{kJ/mol}$  (D) $33 \text{kJ/mol}$  (E) 1.3 J/mol

15. For the reaction $2\text{C(graphite)} + \text{H}_2(g) \rightarrow \text{C}_2\text{H}_2(g)$, $\Delta G^\circ = +209.2 \text{kJ/mol}$ at 25°C. If $P(\text{H}_2) = 100. \text{atm}$, and $P(\text{C}_2\text{H}_2) = 0.10 \text{atm}$, calculate $\Delta G$ for this reaction.
(A) $+207.8 \text{kJ/mol}$  (B) $+226.3 \text{kJ/mol}$  (C) $+192.1 \text{kJ/mol}$  (D) $+17.3 \text{kJ/mol}$  (E) $-16.9 \text{kJ/mol}$

16. What would be the most possible pressure exerted by 10.0 moles of $\text{H}_2$ gas confined in a volume of 2.0 L at 300 K?
(A) 102 atm  (B) 112 atm  (C) 116 atm  (D) 123 atm  (E) 150 atm

17. A gas is compressed in a cylinder from a volume of 20.0 L to 2.0 L by a constant pressure of 10.0 atm. Calculate the amount of work done on the system.
(A) 180 J  (B) $-180 J$  (C) $1.81 \times 10^4 J$  (D) $-1.81 \times 10^4 J$  (E) 18 J

18. $(8.5 + 3.1 + 2.9 + 3.075) / 4$ (Assume that this operation is taking the average of four numbers. Thus 4 in the denominator is exact)
(A) 5  (B) 4.3938  (C) 4.4  (D) 4.39  (E) 4.394

19. Consider a gas in a 5.0 L bulb at STP that is connected via a valve to another bulb that is initially evacuated. When the valve between the two bulbs is opened, what is true about the value of $w$?
(A) It is greater than zero.  (B) It is equal to zero.  (C) It is less than zero.
(D) More information is needed.  (E) None of these.

20. Consider the reaction:
$$2\text{ClF}_3(g) + 2\text{NH}_3(g) \rightarrow \text{N}_2(g) + 6\text{HF}_3(g) + \text{Cl}_2(g), \Delta H < 0$$
Which of the following is true?
(A) The reaction is exothermic.  (B) The reaction is endothermic.  (C) The enthalpy of the
products is less than that of the reactants. (D) Heat is absorbed by the system
(E) Both A and C are true.

21. Balance the following equations:
   \[ a\text{Ca(OH)}_2 + b\text{H}_3\text{PO}_4 \rightarrow c\text{H}_2\text{O} + d\text{Ca}_3(\text{PO}_4)_2 \]
   What is the sum of coefficients \((a+b+c+d)\)?
   (A) 4  (B) 8  (C) 11  (D) 12  (E) 13

22. A certain **Oxygen** atom has the electron configuration \(1s^22s^22p_y^2p_z^1\). How many unpaired electrons are present? Is this an excited state of oxygen?
   (A) 0, No.  (B) 1, Yes.  (C) 2, No.  (D) 2, Yes.  (E) 0, Yes.

23. Which of the following bonds is least polar?
   (A) C—O  (B) H—O  (C) O—Cl  (D) Cl—Cl  (E) They are all nonpolar.

24. Which ion is planar?
   (A) NH\(^+\)  (B) CO\(^3+\)  (C) SO\(_3\)^2−  (D) CH\(_4\)  (E) PCl\(_5\)

25. The hybridization of the central atom in I\(^{-}\) is:
   (A) sp  (B) sp\(^2\)  (C) sp\(^3\)  (D) dsp\(^2\)  (E) d\(^2\)sp\(^3\)

26. How many of the following: \(F_2\), \(B_2\), \(O_2\), \(N_2\), \(Cl_2\) and \(H_2\) are paramagnetic?
   (A) 0  (B) 1  (C) 2  (D) 3  (E) 4

27. Which charge(s) on an \(O_2\) ion would give a bond order of 2.5?
   (A) -3  (B) -1  (C) +1  (D) +2  (E) two of the choices

28. Which of the following aqueous solutions will have the LOWEST vapor pressure? (hint: consider the expected values of van't Hoff factor, \(i\))
   (A) 0.20 m CaH\(_2\)O\(_6\)  (B) 0.20 m NaCl  (C) 0.10 m CaCl\(_2\)  (D) 0.50 m C\(_2\)H\(_5\)OH
   (E) 0.20 m Na\(_2\)SO\(_4\)

29. The reaction:
   \[ A + 2B \rightarrow C \]
   has the following proposed mechanism:
   Step 1: \(A + B \rightarrow D\) (fast)
   Step 2: \(D + A \rightarrow E\)
   Step 3: \(E + B \rightarrow C + A\)

   If step 2 is the rate-determining step, then the rate of formation of \(C\) should equal:
   (A) \(k[A][B]\)  (B) \(k[A][B][D]\)  (C) \(k[A][D][E]\)  (D) \(k[A][B]^2\)  (E) \(k[A]^2[B]\)

30. Which of the following is true for exothermic processes?
   (A) \(\Delta S_{\text{sur}} < 0\)  (B) \(\Delta S_{\text{sur}} = 0\)  (C) \(\Delta S_{\text{sur}} > 0\)  (D) \(\Delta S_{\text{sur}} = \Delta H/T\)  (E) two of these

31. The reaction of 11.9 g of CHCl\(_3\) with excess chlorine produced 7.7 g of CCl\(_4\), carbon tetrachloride:
   \(2\text{CHCl}_3 + 2\text{Cl}_2 \rightarrow 2\text{CCl}_4 + 2\text{HCl}\)

   What is the percent yield?
   (A) 100%  (B) 33.2%  (C) 50.2%  (D) 86%  (E) 44.2%
32. \( iA(g) + jB(g) \rightleftharpoons kC(g) + mD(g) \), Which one of the following statements is NOT correct?

(A) \( K_c = \frac{[C]^k[D]^m}{[A]^i[B]^j} \)

(B) \( K_p = \frac{(P_c)^k(P_d)^m}{(P_a)^i(P_b)^j} \)

(C) \( K_c = K_p \)

(D) \( P_A = C_A RT \), \( C \) represents the molar concentration of the gas.

(E) The forward rate and reverse rate is equal when the reaction at equilibrium position.

33. Which of the following are true at equilibrium for the reaction \( A \rightleftharpoons B \)?

(A) \( [A] \) is equal to \( [B] \)

(B) The overall rate of change of \([B]\) is zero

(C) No new molecules of A are converting into B

(D) The reaction will proceed rapidly from left to right

(E) The value of \([B]/[A]\) is changing in time.

34. Assign the formal charge for each central atom. (1) POCl₃ (2) SO₄²⁻ (3) ClO₄⁻ (4) PO₄³⁻. Which number is equal to the sum of formal charge?

(A) 5 (B) 6 (C) 7 (D) 8 (E) 9

35. Iron is produced from its ore by the following reactions:

\[
2C(s) + O_2(g) \rightarrow 2CO(g);
Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)
\]

How many moles of \( O_2(g) \) are needed to produce 1.4 mol \( Fe(s) \)?

(A) 0.7 mol (B) 1.1 mol (C) 1.5 mol (D) 4.0 mol (E) 2.1 mol

36. Which of the following pairs of compounds can be used to illustrate the law of multiple proportions?

(A) NH₃ and NBr₃ (B) CaO and CaCl₂ (C) H₂O and HI (D) NO and NO₂ (E) CH₄ and CO₂

37. Which of the following species is not amphoteric?

(A) HSO₄⁻ (B) H₂PO₄⁻ (C) HPO₄²⁻ (D) H₂O (E) All of these are amphoteric.

38. The following acids are listed in order of decreasing acid strength in water.

\[ HI > HNO_2 > CH_3COOH > HClO > HCN \]

According to Brønsted-Lowry theory, which of the following ions is the weakest base?

(A) \( \Gamma^- \) (B) \( NO_2^- \) (C) \( CH_3COO^- \) (D) \( Cl^- \) (E) \( CN^- \)

39. Which of the following statements is(are) true?

I. cannot occur independently of each other.

II. accompany all chemical changes.

III. describe the loss and gain of electron(s), respectively.

IV. result in a change in the oxidation states of the species involved.

(A) I only (B) II only (C) III only (D) IV only (E) I, III, and IV

40. In the oxidation of nitric oxide to nitrogen dioxide, If 100.0 mL of NO (at STP) reacts with 400.0 mL of \( O_2 \) at STP, calculate the partial pressure of \( NO_2 \) in the final reaction mixture.
41. Order the following according to increasing rate of effusion:
   \( F_2, Cl_2, NO, NO_2, CH_4 \)
   (A) \( Cl_2 < NO_2 < F_2 < NO < CH_4 \)
   (B) \( Cl_2 < F_2 < NO_2 < CH_4 < NO \)
   (C) \( CH_4 < NO_2 < NO < F_2 < Cl_2 \)
   (D) \( CH_4 < NO < F_2 < NO_2 < Cl_2 \)
   (E) \( F_2 < NO < Cl_2 < NO_2 < CH_4 \)

42. Indicate the mass action expression for the following reaction:
   \( 2X(g) + Y(g) \rightleftharpoons 3W(g) + V(g) \)
   (A) \([X]^2[Y][W]^3[V]\)
   (B) \([X]^2[Y]\)
   (C) \([X]^2[Y][3W][V]\)
   (D) \([2X][Y][W]^3[V]\)
   (E) \([W]^3[V]\)

43. For the reaction \( 2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g) \), what is the relationship between \( K \) and \( K_p \) at temperature \( T \)?
   (A) \( K = K_p \)
   (B) \( K = K_p(RT)^2 \)
   (C) \( K_p = K(2RT) \)
   (D) \( K = K_p(RT) \)
   (E) \( K_p = K(RT) \)

44. Consider the following reaction:
   \( 2HF(g) \rightleftharpoons H_2(g) + F_2(g) \ (K = 1.00 \times 10^{-2}) \)
   Given 1.22 mol of HF(g), 0.760 mol of H_2(g), and 1.09 mol of F_2(g) are mixed in a 4.00-L flask, determine the reaction quotient, \( Q \), and the net direction to achieve equilibrium.
   (A) \( Q = 0.679 \); the equilibrium shifts to the right.
   (B) \( Q = 0.557 \); the equilibrium shifts to the left.
   (C) \( Q = 0.679 \); the equilibrium shifts to the left.
   (D) \( Q = 0.557 \); the equilibrium shifts to the right.
   (E) \( Q = 1.43 \); the system is at equilibrium.

45. Consider a solution of 2.0 \( M \) HCN and 1.0 \( M \) NaCN (\( K_a \) for HCN = \( 6.2 \times 10^{-10} \)). Which of the following statements is true?
   (A) The solution is not a buffer because [HCN] is not equal to [CN\(^-\)].
   (B) The pH will be below 7.00 because the concentration of the acid is greater than that of the base.
   (C) [OH\(^-\)] > [H\(^+\)]
   (D) The buffer will be more resistant to pH changes from addition of strong acid than to pH changes from addition of strong base.
   (E) All of these statements are false.

46. Which of the following statements is(are) true?
47. For a reaction in a voltaic cell, both $\Delta H^\circ$ and $\Delta S^\circ$ are positive. Which of the following statements is true?
   (A) $E^\circ_{\text{cell}}$ will increase with an increase in temperature.
   (B) $E^\circ_{\text{cell}}$ will decrease with an increase in temperature.
   (C) $E^\circ_{\text{cell}}$ will not change when the temperature increases.
   (D) $\Delta G^\circ > 0$ for all temperatures.
   (E) None of the above statements is true.

48. In which groups do all the elements have the same number of valence electrons?
   (A) P, S, Cl (B) Ag, Cd, Ar (C) K, Mg, Ba (D) P, As, Se (E) N, P, As

49. The configuration $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\pi_{2p_y})^1(\pi_{2p_z})^1$ is the molecular orbital description for the ground state of which of the following species?
   (A) Li$^+$ (B) Be$^2$ (C) B$_2$ (D) B$_2^-$ (E) C$_2$

50. For a certain reaction at 25.0°C, the value of $K$ is $1.2 \times 10^{-3}$. At 50.0°C the value of $K$ is $3.4 \times 10^{-1}$. This means that the reaction is
   (A) exothermic (B) endothermic (C) precipitation (D) redox (E) We need more information.