DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records his or her responses. All answers are to be marked on that sheet, not written in the booklet. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet at the end of the examination. Local Sections may use an answer sheet of their own choice.

The full examination consists of 60 multiple-choice questions representing a fairly wide range of difficulty. A periodic table and other useful information are provided on page two of this exam booklet for student reference.

Only non-programmable calculators are to be used on the ACS Local Section exam. The use of a programmable calculator, cell phone, or any other device that can access the internet or make copies or photographs during the exam is grounds for disqualification.

Suggested Time: 60 questions—110 minutes

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

This is a multiple-choice examination with four choices for each question. There is only one correct or best answer to each question. When you select your choice, blacken the corresponding space on the answer sheet with your pencil. Make a heavy full mark, but no stray marks. If you decide to change your answer, be certain to erase your original answer completely.
<table>
<thead>
<tr>
<th>ABBREVIATIONS AND SYMBOLS</th>
<th>CONSTANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>amount of substance ( n )</td>
<td>( R = 8.314 \text{ J mol}^{-1} \text{K}^{-1} )</td>
</tr>
<tr>
<td>ampere ( A )</td>
<td>( R = 0.08314 \text{ L bar} \text{ mol}^{-1} \text{K}^{-1} )</td>
</tr>
<tr>
<td>atmosphere ( atm )</td>
<td>( F = 96,500 \text{ C mol}^{-1} )</td>
</tr>
<tr>
<td>atomic mass unit ( u )</td>
<td>( F = 96,500 \text{ J V}^{-1} \text{mol}^{-1} )</td>
</tr>
<tr>
<td>Avogadro constant ( N_A )</td>
<td>( N_A = 6.022 \times 10^{23} \text{ mol}^{-1} )</td>
</tr>
<tr>
<td>Celsius temperature ( ^\circ C )</td>
<td>( h = 6.626 \times 10^{-34} \text{ J s} )</td>
</tr>
<tr>
<td>centi- prefix ( c )</td>
<td>( c = 2.998 \times 10^8 \text{ m s}^{-1} )</td>
</tr>
<tr>
<td>coulomb ( C )</td>
<td>( 0 ^{\circ} \text{C} = 273.15 \text{ K} )</td>
</tr>
<tr>
<td>density ( d )</td>
<td>( 1 \text{ atm} = 1.013 \text{ bar} = 760 \text{ mm Hg} )</td>
</tr>
<tr>
<td>electromotive force ( E )</td>
<td>Specific heat capacity of H(_2)O = 4.184 J g(^{-1}) K(^{-1})</td>
</tr>
<tr>
<td>energy of activation ( E_a )</td>
<td></td>
</tr>
<tr>
<td>enthalpy ( H )</td>
<td></td>
</tr>
<tr>
<td>entropy ( S )</td>
<td></td>
</tr>
<tr>
<td>equilibrium constant ( K )</td>
<td></td>
</tr>
</tbody>
</table>

\[ E = E^o - \frac{RT}{nF} \ln Q \]

\[ \ln K = \left( \frac{-\Delta H^0}{R} \right) \left( \frac{1}{T} \right) + \text{constant} \]

\[ \ln \left( \frac{k_2}{k_1} \right) = \frac{E_a}{R} \left( \frac{1}{T_i} - \frac{1}{T_f} \right) \]

### PERIODIC TABLE OF THE ELEMENTS

1

<table>
<thead>
<tr>
<th>1A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>1H</td>
</tr>
<tr>
<td>3Li</td>
</tr>
<tr>
<td>11Na</td>
</tr>
<tr>
<td>19K</td>
</tr>
<tr>
<td>37Rb</td>
</tr>
<tr>
<td>55Cs</td>
</tr>
<tr>
<td>87Fr</td>
</tr>
</tbody>
</table>

2

<table>
<thead>
<tr>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>18He</td>
</tr>
<tr>
<td>13Al</td>
</tr>
<tr>
<td>18Ar</td>
</tr>
<tr>
<td>19K</td>
</tr>
<tr>
<td>37Rb</td>
</tr>
<tr>
<td>55Cs</td>
</tr>
<tr>
<td>87Fr</td>
</tr>
</tbody>
</table>

2A

| 58Ce | 59Pr | 60Nd | 61Pm | 62Sm | 63Eu | 64Gd | 65 Tb | 66Dy | 67 Ho | 68Er | 69Tm | 70Yb | 71Lu |
|---|
| 140.1 | 140.9 | 144.2 | (145) | 150.4 | 152.0 | 157.3 | 158.9 | 162.5 | 164.9 | 167.3 | 168.9 | 173.0 | 175.0 |
| 90Th | 91Pa | 92U | 93Np | 94Pu | 95Am | 96Cm | (249) | (251) | (252) | (259) | (262) | |
| 232.0 | 231.0 | 238.0 | 237.0 | 244 | (243) | (245) | (246) | (247) | (250) | (259) | (262) | |
1. At 120 °C and 1 atm pressure, 1.00 L of methane, CH₄, reacts completely with excess oxygen to form carbon dioxide and water. What volumes of the two products are produced at this pressure and temperature?
   (A) 1.00 L CO₂ and 2.00 L H₂O  
   (B) 1.00 L CO₂ and 4.00 L H₂O  
   (C) 2.00 L CO₂ and 2.00 L H₂O  
   (D) 2.00 L CO₂ and 4.00 L H₂O

2. Polypropylene is made by polymerizing propene, C₃H₆ (M = 42.1). How many molecules of propene must be polymerized to make 3.50 g polypropylene?
   (A) 1.43 × 10²²  
   (B) 5.01 × 10²²  
   (C) 6.02 × 10²³  
   (D) 2.11 × 10²⁴

3. An organic compound contains only carbon, hydrogen, nitrogen, and oxygen. It is 61.71% C, 4.03% H, and 16.00% N by mass. What is its empirical formula?
   (A) C₅H₄NO  
   (B) C₉H₇N₂O₂  
   (C) C₁₀H₈N₂O  
   (D) C₁₁H₇NO₂

4. 100.0 mL of 0.500 M CaBr₂ and 50.0 mL of 1.00 M NaBr are mixed. What is the concentration of bromide ion in the resulting solution?
   (A) 0.500 M  
   (B) 0.667 M  
   (C) 0.750 M  
   (D) 1.00 M

5. 1.00 g of hydrated potassium carbonate, K₂CO₃·nH₂O, is heated to 250 °C to give 0.836 g anhydrous K₂CO₃. What is the value of n?
   (A) 0.16  
   (B) 1.0  
   (C) 1.5  
   (D) 2.0

6. The concentration of an aqueous solution of a nonvolatile, monoprotic acid is measured first by freezing point depression and then by boiling point elevation. The solution is found to be 0.93 m by freezing point depression and to be 0.82 m by boiling point elevation. Which is the best explanation for this discrepancy?
   (A) Ionization of the acid is markedly exothermic.  
   (B) The solute associates partially into dimers at lower temperatures.  
   (C) The volume of the solution is greater at higher temperatures.  
   (D) The boiling point elevation constant for water is smaller than its freezing point depression constant.

7. When substances are separated by fractional distillation, which property is least typical of the substance that distills first?
   (A) Highest molar mass  
   (B) Weakest intermolecular forces  
   (C) Greatest vapor pressure  
   (D) Lowest boiling point

8. Which element is most abundant (by mass) in the Earth’s crust?
   (A) Carbon  
   (B) Oxygen  
   (C) Magnesium  
   (D) Silicon

9. Which gas has the highest molar solubility in water at 25 °C and 1 atm?
   (A) CO₂  
   (B) NH₃  
   (C) O₂  
   (D) H₂S

10. Which compound is colorless?
    (A) NaMnO₄  
    (B) CrAsO₄  
    (C) RbIO₄  
    (D) BaCrO₄
11. Chlorine gas is bubbled into a colorless aqueous solution of sodium iodide. Which is the best description of what takes place?
   (A) A precipitate of white NaCl forms.
   (B) A precipitate of metallic Na forms.
   (C) The solution turns pale green as the chlorine dissolves.
   (D) The solution turns yellow-brown as iodide reacts with the chlorine.

12. A student determines the number of moles of water in a hydrated metal oxide by weighing a clean, dry crucible and lid while the crucible is empty, then reweighing the crucible and lid with a sample of the hydrate, heating the crucible and lid with a Bunsen burner and then reweighing the crucible and lid with the sample after cooling to room temperature. Which error will result in too high a value for the amount of water of hydration?
   (A) The heating is conducted only once instead of the three times recommended by the procedure.
   (B) The lid is left off the crucible when it is weighed with the hydrated oxide.
   (C) The metal oxide reacts partially with oxygen in the air, forming a compound in a higher oxidation state.
   (D) Some of the heated oxide is spilled from the crucible before it can be weighed.

13. The diagram is a microscopic view of a snapshot of a substance at equilibrium, with the circles representing molecules and the arrows the molecules' velocities. What state of matter is depicted?
   (A) Solid  (B) Liquid  (C) Gas  (D) Plasma

14. The vapor density of which fluorocarbon is 6.17 g L⁻¹ at 23 °C and 1.00 atm?
   (A) C₃F₆  (B) C₇F₈  (C) C₄F₆  (D) C₂F₈

15. What is the principal intermolecular force that must be overcome when n-hexane (C₆H₁₄, bp = 69 °C) is vaporized?
   (A) Hydrogen bonding
   (B) Covalent bonding between carbon atoms
   (C) Dipole-dipole forces
   (D) London dispersion forces

16. The melting point of water decreases with increasing pressure. Which is the best explanation for this observation?
   (A) Liquid water is denser than solid water at 0 °C.
   (B) Melting of ice is endothermic at 0 °C.
   (C) The vapor pressure of liquid water is lower than the vapor pressure of solid water at 0 °C.
   (D) Solid and liquid water cannot coexist at equilibrium at 0 °C at pressures different from 1 atm.

17. A cylinder containing a mixture of CO and CO₂ has a pressure of 2.00 atm at 93 °C (366 K). The cylinder is then cooled to –90 °C (183 K), where CO is still a gas but CO₂ is a solid with a vapor pressure of 0.25 atm. The pressure in the cylinder at this temperature is 0.90 atm. What is the mole fraction of CO₂ in the cylinder?
   (A) 0.10  (B) 0.28  (C) 0.35  (D) It cannot be determined from the information given.

18. A mineral containing only copper and oxygen adopts the cubic unit cell shown below. What is the formula of this mineral?
   (A) Cu₂O  (B) CuO  (C) Cu₃O₂  (D) Cu₄O₉

19. Burning 48.0 g of graphite in excess oxygen under standard conditions releases 1574.0 kJ of heat. What is ∆H° of CO₂(g)?
   (A) 1574 kJ mol⁻¹  (B) –1574 kJ mol⁻¹
   (C) –394 kJ mol⁻¹  (D) 32.8 kJ mol⁻¹
20. Two metal samples, labeled A and B, absorb the same amount of heat. Sample A has a mass of 10.0 g, and its temperature increases by 38 °C. Sample B has a mass of 20.0 g, and its temperature increases by 23 °C. Which sample has the greater specific heat capacity?

(A) Sample A  
(B) Sample B  
(C) Both samples have the same specific heat capacity.  
(D) It is impossible to determine from the information given.

21. A reaction has \( \Delta S^\circ > 0 \) and \( \Delta H^\circ > 0 \). Which statement about this reaction must be correct?

(A) If carried out in a well-insulated flask, the temperature of the reaction mixture will decrease.  
(B) It will occur spontaneously at 298 K and 1 atm pressure.  
(C) As the temperature is raised, \( K_{eq} \) for this reaction decreases.  
(D) The reaction has more moles of products than it has moles of reactants.

22. What is the boiling point of water in a pressure cooker with a pressure of 2.00 atm? (The enthalpy of vaporization of water is 40.7 kJ mol\(^{-1}\).)

(A) 101 °C  
(B) 121 °C  
(C) 141 °C  
(D) 200 °C

23. The gas-phase bromination of propene has a standard enthalpy of reaction of \(-122.5 \text{ kJ mol}^{-1}\).

\[
\text{C}_3\text{H}_6(g) + \text{Br}_2(g) \rightarrow \text{C}_3\text{H}_6\text{Br}_2(g)  
\Delta H^\circ = -122.5 \text{ kJ mol}^{-1}
\]

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \Delta H^\circ ), kJ mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(_3)H(_6)(g)</td>
<td>20.4</td>
</tr>
<tr>
<td>Br(_2)(g)</td>
<td>30.9</td>
</tr>
</tbody>
</table>

What is the standard enthalpy of formation of \( \text{C}_3\text{H}_6\text{Br}_2(g) \)?

(A) \(-71.2 \text{ kJ mol}^{-1}\)  
(B) \(-102.1 \text{ kJ mol}^{-1}\)  
(C) \(-142.9 \text{ kJ mol}^{-1}\)  
(D) \(-173.8 \text{ kJ mol}^{-1}\)

24. Titanium has a normal melting point of 1668 °C and a molar enthalpy of fusion of 14.15 kJ mol\(^{-1}\). The standard molar entropy of liquid titanium is 97.53 J mol\(^{-1}\) K\(^{-1}\) at 1668 °C. What is the standard molar entropy of solid titanium at this temperature?

(A) 89.05 J mol\(^{-1}\) K\(^{-1}\)  
(B) 90.24 J mol\(^{-1}\) K\(^{-1}\)  
(C) 97.52 J mol\(^{-1}\) K\(^{-1}\)  
(D) 104.82 J mol\(^{-1}\) K\(^{-1}\)

25. In the reaction

\[ \text{Cl}_2(g) + 3 \text{F}_2(g) \rightarrow 2 \text{ClF}_3(g) \]

the rate of disappearance of \( \text{F}_2(g) \) is 1.0 M s\(^{-1}\). What is the rate of appearance of \( \text{ClF}_3(g) \)?

(A) 0.33 M s\(^{-1}\)  
(B) 0.67 M s\(^{-1}\)  
(C) 1.0 M s\(^{-1}\)  
(D) 1.5 M s\(^{-1}\)

26. When the rate of the reversible reaction \( \text{A} + \text{B} \rightleftharpoons \text{C} \) is studied under a certain set of conditions, it is found that the rate of the forward reaction is \( k_\text{f}[\text{A}] \). What can be concluded about the rate law for the reverse reaction under these conditions?

(A) \( \text{Rate} = k_\text{f}[\text{C}] \)  
(B) \( \text{Rate} = k_\text{f}[\text{B}] \)  
(C) The rate law of the reverse reaction cannot be determined from the information given.  
(D) An error must have been made, since if the reaction is reversible, the forward rate law must be \( \text{Rate} = k_\text{f}[\text{A}][\text{B}] \).

27. A substance A decomposes irreversibly to form B. A plot of \( \ln([\text{A}]) \) as a function of time from the beginning of the reaction until A is 97% consumed is a straight line with a negative slope. What is the reaction order in A?

(A) Zero order  
(B) First order  
(C) Second order  
(D) Third order

28. Which statement about catalysis is correct?

(A) If a catalyst increases the forward rate of a reaction by a factor of two, it must increase the rate of the reverse reaction by a factor of two.  
(B) If a catalyst increases the rate of formation of a product by a factor of two, it must increase the rate of formation of the mirror image of the product by a factor of two.  
(C) A catalyst must be in the same phase as the reactants and products of the reaction.  
(D) A catalyzed reaction must proceed by the same mechanism as the uncatalyzed reaction, but with a lower activation energy.

29. The isotope \(^{226}\text{Ra}\) has a half-life for radioactive decay of 1600 y. How long will it take the amount of \(^{226}\text{Ra}\) in a sample of \(^{226}\text{RaCl}_2\) to decrease by 25%?

(A) 660 y  
(B) 800 y  
(C) 1200 y  
(D) 1600 y
30. The oxidation of sulfite ion by triiodide ion is proposed to take place by the following mechanism:

\[
\begin{align*}
&\text{I}_3^- \rightleftharpoons \text{I}_2^- + \text{I}^- \quad \text{fast, unfavorable} \\
&\text{SO}_3^{2-} + \text{I}_2 \rightarrow \text{ISO}_3^- + \text{I}^- \quad \text{slow} \\
&\text{ISO}_3^- + \text{H}_2\text{O} \rightarrow \text{HSO}_4^- + \text{I}^- + \text{H}^+ \quad \text{fast}
\end{align*}
\]

What rate law is predicted by this mechanism?
(A) Rate = \(k[\text{I}_3^-]\)
(B) Rate = \(k[\text{I}_2^-][\text{SO}_3^{2-}]\)
(C) Rate = \(\frac{k[\text{I}_3^-][\text{SO}_3^{2-}]}{[\text{I}^-]}\)
(D) Rate = \(\frac{k[\text{I}_2^-][\text{SO}_3^{2-}]}{[\text{I}^-]}\)

31. What is the correct equilibrium expression for the given reaction?
\[
\text{Cu(OH)}_2(s) + 4 \text{NH}_3(aq) \rightleftharpoons \text{Cu(NH}_3)_4^{2+}(aq) + 2 \text{OH}^-(aq)
\]

\(K_{eq}\) = (A) \(\frac{[\text{Cu(NH}_3)_4^{2+}][\text{OH}^-]}{[\text{NH}_3]^4}\)
(B) \(\frac{[\text{Cu(NH}_3)_4^{2+}][2\text{OH}^-]}{[4\text{NH}_3]}\)
(C) \(\frac{[\text{Cu(NH}_3)_4^{2+}][\text{OH}^-]^2}{[\text{NH}_3]^4}\)
(D) \(\frac{[\text{Cu(NH}_3)_4^{2+}][2\text{OH}^-]^2}{[4\text{NH}_3]^4}\)

32. 0.100 mol of HF \((K_a = 6.6 \times 10^{-4})\) is added to water to make 1.00 L of solution. Which statement is correct at equilibrium?

(A) \([\text{H}_2\text{O}^-] = [\text{HF}]\)
(B) \([\text{H}_3\text{O}^+] = 0.100 \text{ M}\)
(C) \([\text{HF}] > [\text{F}^-]\)
(D) \([\text{H}_3\text{O}^+] > [\text{HF}]\)

33. What is the solubility of silver oxalate, Ag\(_2\)C\(_2\)O\(_4\) \((K_{sp} = 3.5 \times 10^{-14})\), in a 0.050 M sodium oxalate solution?

(A) \(1.4 \times 10^{-6} \text{ M}\)
(B) \(5.9 \times 10^{-6} \text{ M}\)
(C) \(1.3 \times 10^{-5} \text{ M}\)
(D) \(2.1 \times 10^{-4} \text{ M}\)

34. A pure sample of a monoprotic acid is dissolved in water. The sample is titrated with sodium hydroxide solution. At the point where 20.0 mL of the NaOH solution has been added, the pH is 4.15. The phenolphthalein endpoint of the titration is observed when 50.0 mL of NaOH have been added. What is the p\(K_a\) of the acid?

(A) 4.15 (B) 4.33 (C) 4.55 (D) 5.19

35. Consider the reaction:
\[
\text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2 \text{HI}(g) \quad K_{eq} = ???
\]

Into a 1.00 L vessel, 1.00 mol \(\text{H}_2(g)\) and 1.00 mol \(\text{I}_2(g)\) are placed at a high temperature. When the reaction mixture stops changing, it is found that 79.0% of the \(\text{H}_2(g)\) has reacted. What is the equilibrium constant for this reaction at this temperature?

(A) 14.2 (B) 17.9 (C) 35.8 (D) 56.6

36. A triprotic acid is titrated with sodium hydroxide to give the titration curve below. What are the p\(K_a\) values of the three acidic hydrogens?

![Titration Curve](image)

(A) 2.6, 5.0, 8.2 (B) 3.8, 6.6, 10.6
(C) 3.8, 8.2, 12.7 (D) 5.0, 8.2, 12.7

37. What is the average oxidation state of tin in the mineral abhurite, \(\text{Sn}_2\text{Cl}_{16}\text{(OH)}_4\text{O}_2\)?

(A) +1.71 (B) +2.00 (C) +2.76 (D) +3.43

38. If used in an electrochemical cell, which of the following half-reactions would require an inert electrode?

I. \(2 \text{Cl}^-(aq) \rightleftharpoons \text{Cl}_2(g) + 2 e^-\)
II. \(\text{Fe(CN)}_6^{3-}(aq) + e^- \rightleftharpoons \text{Fe(CN)}_6^{4-}(aq)\)

(A) I only (B) II only
(C) Both I and II (D) Neither I nor II

39. Chromium is electroplated industrially by the electrolysis of solutions of \(\text{K}_2\text{Cr}_2\text{O}_7\). How much time would be required to deposit 1.00 kg of Cr using a current of 200.0 A?

(A) 2.58 h (B) 7.74 h (C) 15.5 h (D) 31.0 h
40. What is the standard reduction potential of Cr^{3+}(aq) to form metallic chromium?

\[
\begin{array}{|c|c|}
\hline
\text{Half-reaction} & E^0, \text{ V} \\
\hline
\text{Cr}^{3+}(aq) + e^- \rightarrow \text{Cr}^{2+}(aq) & -0.41 \\
\text{Cr}^{3+}(aq) + 2e^- \rightarrow \text{Cr}(s) & -0.91 \\
\text{Cr}^{3+}(aq) + 3e^- \rightarrow \text{Cr}(s) & ??
\hline
\end{array}
\]

(A) -0.74 V  (B) -1.32 V  (C) -1.73 V  (D) -2.23 V

41. What is the equilibrium constant at 298 K for the disproportionation of uranium(V) in acidic solution as shown below?

\[
2 \text{UO}_2^{2+}(aq) + 4 \text{H}^+(aq) \leftrightarrow \text{UO}_2^{3+}(aq) + \text{U}^{4+}(aq) + 2 \text{H}_2\text{O}(l)
\]

\[K_{eq} = ??\]

\[
\begin{array}{|c|c|}
\hline
\text{Half-reaction} & E^0, \text{ V} \\
\hline
\text{UO}_2^{2+}(aq) + e^- \rightarrow \text{UO}_2^{3+}(aq) & +0.16 \\
\text{UO}_2^{3+}(aq) + 4 \text{H}^+(aq) + e^- \rightarrow \text{U}^{4+}(aq) + 2 \text{H}_2\text{O}(l) & +0.27
\hline
\end{array}
\]

(A) 1.9 \times 10^{-4}  (B) 73  (C) 5300  (D) 1.9 \times 10^{7}

42. The standard reduction potential \(E^0\) for the reduction of permanganate in acidic solution is +1.51 V. What is the reduction potential for this half-reaction at pH = 5.00?

\[
\text{MnO}_4^-(aq) + 8 \text{H}^+(aq) + 5 e^- \rightarrow \text{Mn}^{2+}(aq) + 4 \text{H}_2\text{O}(l)
\]

\[E^0 = +1.51 \text{ V} \]

(A) +1.50 V  (B) +1.42 V  (C) +1.04 V  (D) -0.85 V

43. Which is a possible set of quantum numbers \(n, l, m_s, m_s\) for a valence electron of sulfur (S)?

(A) 3, 2, 2, 1/2  (B) 3, 1, -1, 1/2  (C) 2, 1, 0, 1/2  (D) 3, 2, 0, -1/2

44. Which period 3 element has these successive ionization energies (in kJ mol\(^{-1}\))? 

\[
\begin{array}{|c|c|c|c|}
\hline
IE_1 & IE_2 & IE_3 & IE_4 \\
\hline
786.5 & 1577.1 & 3231.6 & 4355.5 \\
16091 & 19805 & 23780 & \\
\hline
\end{array}
\]

(A) Al  (B) Si  (C) P  (D) S

45. Which is the ground-state electron configuration of gas-phase Co\(^{2+}\)?

(A) \(1s^22s^22p^63s^23p^63d^6\)  (B) \(1s^22s^22p^63s^23p^63d^8\)  (C) \(1s^22s^22p^63s^23p^64s^24d^6\)  (D) \(1s^22s^22p^63s^23p^64d^4d^9\)

46. A fluorescent dye absorbs a photon of light of 485 nm and emits a photon of light at 540 nm. How much energy is lost as heat?

\(\text{(A) } 4.17 \times 10^{-20} \text{ J} \quad \text{ (B) } 3.68 \times 10^{-19} \text{ J} \quad \text{ (C) } 4.10 \times 10^{-19} \text{ J} \quad \text{ (D) } 3.06 \times 10^{-18} \text{ J}\)

47. Which gas-phase atom releases the most energy when an electron is added to it?

\(\text{(A) } \text{Na} \quad \text{(B) } \text{Cl} \quad \text{(C) } \text{K} \quad \text{(D) } \text{Br}\)

48. The isotope \(^{44}\text{Ti}\) undergoes electron capture. Which daughter isotope is produced?

\(\text{(A) } ^{40}\text{K} \quad \text{(B) } ^{40}\text{Ca} \quad \text{(C) } ^{44}\text{Sc} \quad \text{(D) } ^{44}\text{V}\)

49. Which species has the strongest carbon-oxygen bond?

\(\text{(A) } \text{CO} \quad \text{(B) } \text{CO}_2 \quad \text{(C) } \text{CH}_2\text{O} \quad \text{(D) } \text{CH}_3\text{OH}\)

50. Which molecule has a nonzero dipole moment?

\(\text{(A) } \text{O}_2 \quad \text{(B) } \text{O}_3 \quad \text{(C) } \text{S}_8 \quad \text{(D) } \text{SO}_3\)

51. Which statement best describes the structure and bonding in nitromethane, \(\text{H}_3\text{C}-\text{NO}_2\)?

\(\text{(A) } \text{Each of the three bonds to nitrogen is a different length.} \quad \text{(B) } \text{The molecule is Lewis acidic because the nitrogen does not obey the octet rule.} \quad \text{(C) } \text{The molecule is Lewis basic because the nitrogen has a lone pair.} \quad \text{(D) } \text{The nitrogen atom has a trigonal planar geometry.}\)

52. Which statements about the superoxide ion, \(\text{O}_2^-\), are correct?

\(\text{I. It has a bond order of 2.0.} \quad \text{II. It has exactly one unpaired electron.} \quad \text{II. It has exactly one unpaired electron.} \quad \text{I. It has a bond order of 2.0.}\)

\(\text{(A) } \text{I only} \quad \text{(B) } \text{II only} \quad \text{(C) } \text{Both I and II} \quad \text{(D) } \text{Neither I nor II}\)
53. Which structure best depicts the three-dimensional shape of the P₄ molecule?

(A) \[
\begin{array}{c}
\text{P} \\
\text{P} \\
\text{P} \\
\text{P}
\end{array}
\]

(B) \[
\begin{array}{c}
\text{P} \\
\text{P} \\
\text{P} \\
\text{P}
\end{array}
\]

(C) \[
\begin{array}{c}
\text{P} \\
\text{P} \\
\text{P} \\
\text{P}
\end{array}
\]

(D) \[
\begin{array}{c}
\text{P} \\
\text{P} \\
\text{P} \\
\text{P}
\end{array}
\]

54. How many isomers are there of the octahedral coordination complex Co(NH₃)₃Cl₃?

(A) 1  (B) 2  (C) 3  (D) 4

55. Which is NOT a valid representation of 3-methyl-1-butene?

(A) (CH₃)₂CH=CH₂  (B) CH₂CHCH(CH₃)₂

(C) \[
\begin{array}{c}
\text{CH₃} \\
\text{CH₃} \\
\text{CH₃} \\
\text{CH₃}
\end{array}
\]

(D) \[
\begin{array}{c}
\text{CH₃} \\
\text{CH₃} \\
\text{CH₃} \\
\text{CH₃}
\end{array}
\]

56. What is the relationship between the two compounds shown?

(A) Identical  (B) Structural isomers  (C) Geometric isomers  (D) Mirror image isomers

57. An amine with the formula C₄H₁₁N will have which of these properties?

(A) Unpleasant odor  (B) Boiling point greater than 100 °C  (C) Absorption of light with \( \lambda > 450 \text{ nm} \)  (D) Water solubility less than 10 g/L

58. Which combination of reactants and catalyst will produce methyl propanoate, CH₃CH₂COOCH₃, upon heating?

(A) CH₃CH₂OH and CH₃COOH with catalytic NaOH  (B) CH₃CH₂OH and CH₃COOH with catalytic H₂SO₄

(C) CH₃OH and CH₃CH₂COOH with catalytic NaOH  (D) CH₃OH and CH₃CH₂COOH with catalytic H₂SO₄

59. Which conformation of cyclohexane (C₆H₁₂) is most stable?

(A) \[
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

(B) \[
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

(C) \[
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

(D) \[
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

60. Which element is NOT present in DNA?

(A) H  (B) N  (C) P  (D) S

END OF TEST
<table>
<thead>
<tr>
<th>Number</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A</td>
</tr>
<tr>
<td>2.</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>B</td>
</tr>
<tr>
<td>4.</td>
<td>D</td>
</tr>
<tr>
<td>5.</td>
<td>C</td>
</tr>
<tr>
<td>6.</td>
<td>A</td>
</tr>
<tr>
<td>7.</td>
<td>A</td>
</tr>
<tr>
<td>8.</td>
<td>B</td>
</tr>
<tr>
<td>9.</td>
<td>B</td>
</tr>
<tr>
<td>10.</td>
<td>C</td>
</tr>
<tr>
<td>11.</td>
<td>D</td>
</tr>
<tr>
<td>12.</td>
<td>D</td>
</tr>
<tr>
<td>13.</td>
<td>B</td>
</tr>
<tr>
<td>14.</td>
<td>A</td>
</tr>
<tr>
<td>15.</td>
<td>D</td>
</tr>
<tr>
<td>16.</td>
<td>A</td>
</tr>
<tr>
<td>17.</td>
<td>C</td>
</tr>
<tr>
<td>18.</td>
<td>A</td>
</tr>
<tr>
<td>19.</td>
<td>C</td>
</tr>
<tr>
<td>20.</td>
<td>A</td>
</tr>
<tr>
<td>21.</td>
<td>A</td>
</tr>
<tr>
<td>22.</td>
<td>B</td>
</tr>
<tr>
<td>23.</td>
<td>A</td>
</tr>
<tr>
<td>24.</td>
<td>B</td>
</tr>
<tr>
<td>25.</td>
<td>B</td>
</tr>
<tr>
<td>26.</td>
<td>B</td>
</tr>
<tr>
<td>27.</td>
<td>B</td>
</tr>
<tr>
<td>28.</td>
<td>A</td>
</tr>
<tr>
<td>29.</td>
<td>A</td>
</tr>
<tr>
<td>30.</td>
<td>C</td>
</tr>
<tr>
<td>31.</td>
<td>C</td>
</tr>
<tr>
<td>32.</td>
<td>C</td>
</tr>
<tr>
<td>33.</td>
<td>C</td>
</tr>
<tr>
<td>34.</td>
<td>B</td>
</tr>
<tr>
<td>35.</td>
<td>D</td>
</tr>
<tr>
<td>36.</td>
<td>A</td>
</tr>
<tr>
<td>37.</td>
<td>B</td>
</tr>
<tr>
<td>38.</td>
<td>C</td>
</tr>
<tr>
<td>39.</td>
<td>C</td>
</tr>
<tr>
<td>40.</td>
<td>A</td>
</tr>
<tr>
<td>41.</td>
<td>B</td>
</tr>
<tr>
<td>42.</td>
<td>C</td>
</tr>
<tr>
<td>43.</td>
<td>B</td>
</tr>
<tr>
<td>44.</td>
<td>B</td>
</tr>
<tr>
<td>45.</td>
<td>D</td>
</tr>
<tr>
<td>46.</td>
<td>A</td>
</tr>
<tr>
<td>47.</td>
<td>B</td>
</tr>
<tr>
<td>48.</td>
<td>C</td>
</tr>
<tr>
<td>49.</td>
<td>A</td>
</tr>
<tr>
<td>50.</td>
<td>B</td>
</tr>
<tr>
<td>51.</td>
<td>D</td>
</tr>
<tr>
<td>52.</td>
<td>B</td>
</tr>
<tr>
<td>53.</td>
<td>D</td>
</tr>
<tr>
<td>54.</td>
<td>B</td>
</tr>
<tr>
<td>55.</td>
<td>C</td>
</tr>
<tr>
<td>56.</td>
<td>C</td>
</tr>
<tr>
<td>57.</td>
<td>A</td>
</tr>
<tr>
<td>58.</td>
<td>D</td>
</tr>
<tr>
<td>59.</td>
<td>B</td>
</tr>
<tr>
<td>60.</td>
<td>D</td>
</tr>
</tbody>
</table>