Q1.
Which of the following diatomic species is paramagnetic?

A) $\text{O}_2$
B) $\text{N}_2$
C) $\text{F}_2$
D) $\text{CO}$
E) $\text{NO}^+$

Q2.
Which of the following statements about the $\text{CO}_3^{2-}$ ion is false?

A) One C–O bond is shorter than the other.
B) The orbitals on the carbon atom are $\text{sp}^2$ hybridized.
C) The ion has three resonance structures.
D) The ion has a total of 24 valence electrons.
E) The ion has 3 sigma bonds.

Q3.
The hybridization of the central atom in $\text{XeF}_5^+$ and $\text{ClF}_3$ are,

A) $d^2\text{sp}^3$ and $\text{dsp}^3$ respectively.
B) $\text{dsp}^3$ and $\text{sp}^2$ respectively.
C) $\text{dsp}^3$ and $\text{sp}^3$ respectively.
D) $d^2\text{sp}^3$ and $\text{sp}^3$ respectively.
E) $d^2\text{p}^3$ and $d^2\text{sp}^3$ respectively.

Q4.
Which of the following has the highest bond order?

A) $\text{O}_2^{2+}$
B) $\text{O}_2^+$
C) $\text{O}_2$
D) $\text{O}_2^-$
E) $\text{O}_2^{2-}$

Q5.
Which of the following electron configurations is correct for CO by the molecular orbital model?

A) $(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^2$
B) $(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^4$
C) $(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4$
D) $(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\sigma_{2p})^2 (\pi_{2p})^4 (\pi_{2p}^*)^2$
Q6. Which of the following would show hydrogen bonding?

\[
E) \quad (\sigma_{2s})^2 (\pi_{2p})^4 (\sigma_{2p}^*)^2
\]

<table>
<thead>
<tr>
<th></th>
<th>hydrogen</th>
<th>dimethyl ether</th>
<th>formaldehyde</th>
<th>hydrogen peroxide</th>
<th>hydrazine</th>
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<tbody>
<tr>
<td>(i)</td>
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<td>(ii)</td>
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<td>(v)</td>
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</tbody>
</table>

A) (iv) and (v) only  
B) (i), (iv) and (v) only  
C) (iii), (iv) and (v) only  
D) all compounds except (i)  
E) all compounds except (ii)

Q7. Of the following, the substance with the highest melting point is

A) calcium fluoride  
B) fluorine  
C) dioxygen difluoride  
D) silicon tetrafluoride  
E) phosphorous pentafluoride

Q8. The element iron crystallizes in a form called \(\alpha\)-iron, which has a body-centered cubic unit cell. The body-centered cubic unit cell of \(\alpha\)-iron is 0.28864 nm on each side. Calculate the density of this form of iron.

A) 7.713 g/cm\(^3\)  
B) 15.43 g/cm\(^3\)  
C) 3.857 g/cm\(^3\)  
D) 1.841g/cm\(^3\)  
E) 3.683 g/cm\(^3\)

Q9. Ethanol (\(C_2H_5OH\)) melts at \(-114.0^{\circ}\)C and boils at \(78.0^{\circ}\)C. How much heat is required to convert 75.0 g of ethanol at \(-120.0^{\circ}\)C to the vapor phase at \(78.0^{\circ}\)C?

Enthalpy of fusion \(\Delta H_{\text{fus}}\) of ethanol = 5.02 kJ/mol  
Enthalpy of vaporization \(\Delta H_{\text{vap}}\) of ethanol = 38.56 kJ/mol  
Specific heat of solid ethanol = 0.970 J/g.\(^{\circ}\)C
Specific heat of liquid ethanol = 2.300 J/g.°C

A) 105 kJ
B) 3.30 x 10^3 kJ
C) 88.8 kJ
D) 91.5 kJ
E) 71.7 kJ

Q10.
Octane, C_{8}H_{18}, is the principal component of gasoline. It has a vapor pressure of 145 mm Hg at 75.0°C and 20.0 mm Hg at 32.0°C. Calculate its vapor pressure at 85.0°C.

A) 215 mm Hg.
B) 173 mm Hg
C) 142 mm Hg
D) 128 mm Hg
E) 56.8 mm Hg

Q11.
Which of the following substances can be liquefied by applying pressure at 25°C?

<table>
<thead>
<tr>
<th>SUBSTANCE</th>
<th>CRITICAL TEMPERATURE</th>
<th>CRITICAL PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Sulfur dioxide</td>
<td>158°C</td>
<td>78 atm</td>
</tr>
<tr>
<td>(ii) Acetylene</td>
<td>36°C</td>
<td>62 atm</td>
</tr>
<tr>
<td>(iii) Methane</td>
<td>−82°C</td>
<td>46 atm</td>
</tr>
<tr>
<td>(iv) Carbon monoxide</td>
<td>−140°C</td>
<td>35 atm</td>
</tr>
</tbody>
</table>

A) (i) and (ii) only.
B) (iii) and (iv) only.
C) All substances.
D) The given information is not enough to answer this question.
E) (i) and (iv) because of being polar compounds.

Q12.
Cobalt fluoride crystallizes in a cubic closed packed array in which fluoride ions forms face-centered cubic structure with the cobalt ions filling one-half of the octahedral holes. What is the formula of this compound?

A) CoF_2
B) CoF_3
C) Co_2F_5
D) Co_3F_4
E) CoF
Q13.
Give the result of the following mathematical operations to the correct number of significant figures.

\[
3.21 \times (26 + 3.431) \div 4.731
\]

A) 20.
B) 19.9
C) 19.96
D) 18.3
E) 35

Q14.
It is estimated that uranium is relatively common in the earth’s crust, occurring in amounts of 4 g/metric ton. A metric ton is 1000 kg. At this concentration, what mass of uranium is present in 1.0 mg of the earth’s crust?

A) 4 nanograms
B) 4 micrograms
C) 4 milligrams
D) 4 x 10^{-5} g
E) 4 centigrams

Q15.
With what volume of 5.0 M HF will 7.4 g of calcium hydroxide react completely, according to the following reaction?

\[2 \text{HF} + \text{Ca(OH)}_2 \rightarrow \text{CaF}_2 + 2\text{H}_2\text{O}\]

A) 40. mL
B) 50. mL
C) 30. mL
D) 20. mL
E) 1.0 x 10^2 mL

Q16.
Balance the following oxidation–reduction reaction using the half-reaction method.

\[\text{Cr}_2\text{O}_7^{2-} + \text{I}_2 \rightarrow \text{Cr}^{3+} + \text{IO}_3^- \] (acidic solution)
In the balanced equation, the coefficient of water is,

A) 17
B) 4
C) 11
D) 7
E) 6

Q17.
A 1.000-g sample of a metal chloride, MCl₂, is dissolved in water and treated with excess aqueous silver nitrate. The silver chloride that formed weighed 1.286 g. Calculate the atomic mass of M.

A) 152.0 g/mol
B) 76.00 g/mol
C) 222.8 g/mol
D) 304.0 g/mol
E) 453.0 g/mol

Q18.
In a certain condition, nitrogen reacts with oxygen to form two compounds. The mass of oxygen that combines with 1.00 g of nitrogen for each compound is 2.286 g and 3.429 g respectively. The ratio of the masses of nitrogen in these two compounds would be,

A) 2/3
B) 1/2
C) 1/3
D) 2/1
E) 3/1

Q19.
Name the compound CoPO₄.

A) Cobalt(III) phosphate
B) Cobalt(II) phosphate
C) Cobalt(II) phosphide
D) Cobalt phosphate
E) Cobalt(III) phosphide

Q20.
An inflated balloon has a volume of 7.5 L at sea level (1.0 atm) and is allowed to rise to a point in the atmosphere where the pressure is 0.45 atm. During rise the
The temperature of the gas falls from 22°C to –21°C. Calculate the volume of the balloon at its final height.

A) 14 L  
B) 20. L  
C) 16 L  
D) 2.9 L  
E) 6.4 L

Q21.
The safety airbags in automobiles are inflated (blown) by nitrogen gas generated by the rapid decomposition of sodium azide, NaN₃,

$$2\text{NaN}_3(s) \rightarrow 2\text{Na}(s) + 3\text{N}_2(g)$$

If an air bag has a volume of 37.0 L and is to be filled with nitrogen gas at a pressure of 1.15 atm at a temperature of 25.0°C, how many grams of NaN₃ must be decomposed?

A) 75.4 g  
B) 1.70 x 10² g  
C) 113 g  
D) 146 g  
E) 37.7 g

Q22.
In an effusion experiment, 12.0 seconds are required for 1.00 L of O₂ to effuse through a pinhole. How long will it take for the same volume of NO₂ to effuse under identical conditions?

A) 14.4 sec  
B) 17.3 sec  
C) 15.6 sec  
D) 12.0 sec  
E) 10.0 sec

Q23.
Consider the following reaction;

$$4\text{Fe}(s) + 3\text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3(s) \quad \Delta H = -1652 \text{ kJ}$$

How much heat is released when 10.0 g Fe is reacted with excess O₂?

A) -73.9 kJ  
B) -34.4 kJ
Q24.
A 30.0 g sample of water at 280. K is mixed with 50.0 g of water at 330. K. What is the final temperature of the mixture assuming no heat loss to the surroundings? Specific heat of water = 4.18 J/g °C

A) 311 K
B) 150 K
C) 75 K
D) 235 K
E) 305 K

Q25.
The de Broglie wavelength of an electron (mass = 9.11 x 10^{-31} kg) with a velocity 10.% of the speed of light would be,

A) 2.4 x 10^{-11} m
B) 1.32 x 10^{-13} m
C) 4.4 x 10^{-34} m
D) 3.6 x 10^{-10} m
E) 3.52 x 10^{-7} m

Q26.
The successive ionization energies for an unknown element are $I_1 = 896$ kJ/mol, $I_2 = 1752$ kJ/mol, $I_3 = 14807$ kJ/mol, $I_4 = 17948$ kJ/mol. To which family in the periodic table does the unknown element most likely belong?

A) Alkaline earth metals
B) Alkali metals
C) Transition metals
D) Halogens
E) Noble gases

Q27.
In the ground state of cadmium, Cd, how many electrons have $m_l = -1$ as one of their quantum numbers?

A) 10
B) 18
C) 24
D) 48
E) 5
Q28.
Given the bond energies (in kJ/mol) for H—H, Br—Br, and H—Br as 436, 193, and 368 respectively, calculate the heat of formation of H—Br from gaseous H₂ and Br₂.

A) -54 kJ/mol  
B) -65 kJ/mol  
C) -107 kJ/mol  
D) -131 kJ/mol  
E) -150 kJ/mol

Q29.
Which one of the following compounds does not obey the octet rule?

A) PF₅  
B) NF₃  
C) AsH₃  
D) CF₄  
E) CO₂

Q30.
Arrange the following ions in order of decreasing size.

I⁻, Cs⁺, La³⁺, Ba²⁺, Te²⁻

A) Te²⁻ > I⁻ > Cs⁺ > Ba²⁺ > La³⁺  
B) Te²⁻ > Ba²⁺ > Cs⁺ > I⁻ > La³⁺  
C) Te²⁻ > Cs⁺ > Ba²⁺ > I⁻ > La³⁺  
D) La³⁺ > Ba²⁺ > Cs⁺ > I⁻ > Te²⁻  
E) I⁻ > Cs⁺ > Te²⁻ > La³⁺ > Ba²⁺

Q31.
A compound contains only carbon, hydrogen, and oxygen. Combustion of 10.86 mg of the compound yields 16.01 mg CO₂ and 4.37 mg H₂O. The molar mass of the compound is 176.1 g/mol. What is the molecular formula of the compound?

A) C₆H₈O₆  
B) C₆H₁₂O₆  
C) C₂H₅O₄  
D) C₃H₈O₃  
E) C₃H₁₂O₉

Q32.
Natural rubidium has the average mass of 85.4678 amu and is composed of isotopes $^{85}$Rb (mass = 84.9117 amu) and $^{87}$Rb. The ratio of atoms $^{85}$Rb/$^{87}$Rb in natural rubidium is 2.591. Calculate the mass of $^{87}$Rb.
Q33. Considering the following unbalanced reaction:

\[ \text{B}_5\text{H}_9(\text{l}) + \text{O}_2(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) \]

If 126 g of \( \text{B}_5\text{H}_9 \) is mixed with 192 g of \( \text{O}_2 \), what mass of water will be produced?

A) 81.1 g  
B) 144 g  
C) 50.5 g  
D) 15.2 g  
E) 35.8 g

Q34. The freezing point of a solution of \( \text{NaCl} \) in 1.00 kg of water was found to be \(-0.426^\circ\text{C}\). Assuming ideal behavior, calculate the mass of \( \text{NaCl} \) in solution.

Molal freeze-point depression constant \( K_f \) of water = 1.86 °C.kg/mol

A) 6.69 g  
B) 13.3 g  
C) 25.2 g  
D) 8.75 g  
E) 38.2 g

Q35. A bottle contains 12.5% ethanol (\( \text{C}_2\text{H}_5\text{OH} \)) by volume. The density of ethanol is 0.789 g/cm\(^3\). Calculate the molality of ethanol. (Density of water = 1.00 g/cm\(^3\))

A) 2.45 m  
B) 5.24 m  
C) 1.52 m  
D) 12.3 m
Q36. The vapor pressure of a solution containing 53.6 g glycerin (C₃H₈O₃) in 133.7 g ethanol (C₂H₅OH) is 11.3 torr at 40°C. Calculate the vapor pressure of pure ethanol at 40°C assuming that glycerin is nonvolatile, nonelectrolyte solute in ethanol.

A) 13.6 torr  
B) 9.41 torr  
C) 36.6 torr  
D) 25.3 torr  
E) 42.3 torr

Q37. A sample weighing 1.00x10⁻³ g was dissolved in water to make 1.00 mL solution. The osmotic pressure of the solution was found to be 1.12 torr at 25.0°C. Calculate the molar mass of the sample.

A) 1.66 x 10⁴ g/mol  
B) 2.45 x 10⁴ g/mol  
C) 3.45 x 10⁵ g/mol  
D) 6.23 x 10³ g/mol  
E) 4.57 x 10⁶ g/mol

Q38. The solubility of nitrogen in water is 8.21 x 10⁻⁴ mol/L at 0°C when the N₂ pressure above water is 0.790 atm. Calculate the solubility of N₂ in water when the partial pressure of nitrogen above water is 1.10 atm at 0°C.

A) 1.14 x 10⁻³ mol/L  
B) 2.04 x 10⁻³ mol/L  
C) 8.26 x 10⁻² mol/L  
D) 1.56 x 10⁻⁴ mol/L  
E) 5.26 x 10⁻¹ mol/L

Q39. Which of the following aqueous solutions has the lowest freezing point?

A) 0.15 m Na₂SO₄  
B) 0.18 m KCl  
C) 0.12 m Ca(NO₃)₂  
D) pure water  
E) 0.20 m C₂H₆O₂ (ethylene glycol)
Glycerine, $C_3H_8O_3$, is a nonvolatile liquid. What is the vapor pressure of the solution made by adding 164 g of glycerine to 338 mL of water($H_2O$) at 39.8°C?

Vapor pressure of pure water at 39.8°C = 54.74 torr
Density of water at 39.8°C = 0.992 g/cm$^3$

A) 50.0 torr  
B) 65.2 torr  
C) 43.7 torr  
D) 123 torr  
E) 25.0 torr