Kalamazoo Section
American Chemical Society (KACS)

COMPETITIVE SCHOLARSHIPS IN CHEMISTRY

March 2025

Student Name_____

ACS ID Number_____

A periodic table and scantron sheet are provided. No other charts or tables are permitted.

Write your **first** and **last name** and **ACS ID number** on the scantron sheet and blacken the spaces that correspond to your answer.

Non-programmable scientific calculators may be used, but not shared.

1. A 25.25 g sample of Na_2CO_3 is dissolved in enough water to make 0.500 L of solution. What volume of this solution must be diluted with water to make 0.250 L of 0.200 M Na_2CO_3?

   a. 58 mL
   b. 104 mL
   c. 216 mL
   d. 325 mL

2. Which of the following statements correctly describes the reactivity of alkaline earth metals (Group 2) with water?

   a. Magnesium reacts very violently with water, producing hydrogen gas and magnesium hydroxide.
   b. Calcium reacts more readily with water than magnesium, and barium reacts more vigorously than calcium.
   c. Beryllium is the most reactive alkaline earth metal with water, producing hydrogen gas and a large amount of heat.
   d. The reactivity of alkaline earth metals with water decreases as you move down the group, from beryllium to barium.

Questions 3 and 4 refer to the following information:
Hydrazine (N_2H_4) reacts with dinitrogen tetroxide (N_2O_4) to produce nitrogen gas (N_2) and water (H_2O) according to the following reaction:

$$2\ N_2H_4\ (g) + N_2O_4\ (g) \rightarrow 3\ N_2\ (g) + 4\ H_2O\ (g)$$

Consider the reaction of 8.0 g of N_2H_4 with 32.0 g of N_2O_4.

3. The limiting reactant is

   a. N_2H_4
   b. N_2O_4
   c. N_2
   d. H_2O

4. What is the maximum volume of water (H_2O) that can be produced at STP?

   a. 47.7 L
   b. 22.4 L
   c. 13.1 L
   d. 6.0 L

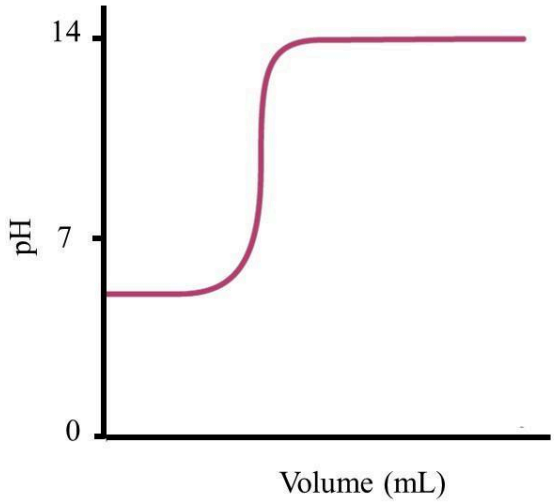
5. In an experiment, a 5.0 g sample of a transition metal carbonate, MCO_3, is heated and decomposes to produce a metal oxide and carbon dioxide gas, according to the following reaction:

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

After heating, the mass of the metal oxide produced is found to be 3.1 grams. Based on this information, determine which transition metal is most likely represented by M.

a. Iron (Fe)
b. Copper (Cu)
c. Zinc (Zn)
d. Chromium (Cr)

6. Which of the following titrations would most likely produce a titration curve shown in the figure below?



a. Strong acid titrated with strong base
b. Weak acid titrated with strong base
c. Strong acid titrated with weak base
d. Weak acid titrated with weak base

7. Three saturated solutions are prepared at 25°C as outlined in the table below.

Solution	Solute	K_{sp} at 25°C
A	AgCl	1.8×10^{-10}
B	AgBr	5.0×10^{-13}
C	AgI	8.3×10^{-17}

Which of the following lists the solutions in order of increasing concentration of silver ions?

a. A < C < B
b. B < A < C
c. C < B < A
d. B < C < A

8. A solution is prepared by mixing 0.10 M HCl and 0.10 M acetic acid (CH_3COOH). Which statement best describes the expected conductivity?

   a. The solution will conduct electricity less effectively than 0.10 M HCl alone.
   b. The solution will conduct electricity more effectively than 0.10 M HCl alone.
   c. The solution will conduct electricity more effectively than 0.10 M acetic acid alone.
   d. The conductivity will be independent of the acetic acid.

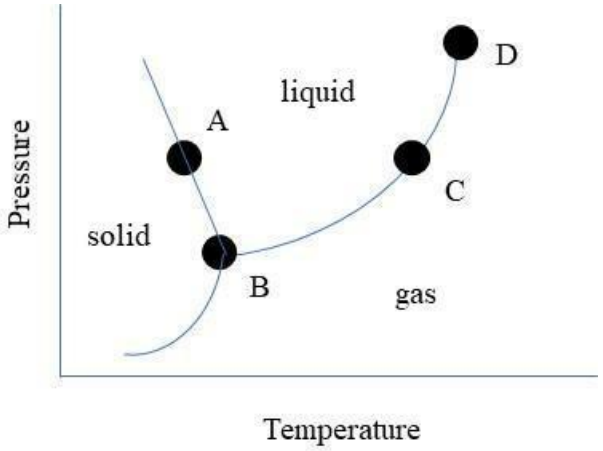
9. What ion produces a purple flame when burned?

   a. Calcium
   b. Potassium
   c. Sodium
   d. Lithium

10. What is the final pressure when 4.0 L of He(*g*), 6.0 L of N_2(*g*) and 10.0 L of Ar(*g*) at 0°C and 1.0 atm are pumped into an evacuated 8.0 L chamber at 0°C?

    a. 4.0 atm
    b. 2.5 atm
    c. 1.5 atm
    d. 0.5 atm

11. The phase diagram of a water is shown below. Which point indicates the normal freezing point?



    a. A
    b. B
    c. C
    d. D

12. Which statement best explains the relationship between temperature and the kinetic energy of gas particles according to the Kinetic Molecular Theory?

a. As temperature increases, the average kinetic energy of the gas particles decreases because the particles move more slowly.
b. As temperature increases, the average kinetic energy of the gas particles increases and the frequency of collision between particles decreases.
c. The kinetic energy of gas particles is independent of temperature and is only affected by the volume and pressure of the gas.
d. The temperature of a gas is directly proportional to the average kinetic energy of the gas particles which increases with increasing temperature.

13. Consider the two compounds below:

CH_3-CH_2-N$(CH_3)_2$ Compound A CH_3-CH_2-CH_2-CH_2-NH_2 Compound B

Which statement accurately identifies the compound with the higher boiling point?

a. Compound A because it has weaker London dispersion forces.
b. Compound A because it forms hydrogen bonds.
c. Compound B because it forms hydrogen bonds.
d. Compound B because it has weaker London dispersion forces.

14. How much energy is needed to raise the temperature of 4.0g of ice from -10°C to 32°C?

C_{ice} = 0.5 cal/g°C
C_{water} = 1.0 cal/g°C
ΔH_{fusion} = 80 cal/g

a. 148 cal
b. 172 cal
c. 320 cal
d. 468 cal

15. Calculate the ΔH for the reaction below, given the following information:

$H_2SO_4(l) \rightarrow SO_3(g) + H_2O(g)$

$H_2S(g) + 2\ O_2(g) \rightarrow H_2SO_4(l)\ \Delta H = -235$ kJ
$H_2S(g) + 2\ O_2(g) \rightarrow SO_3(g) + H_2O(l)\ \Delta H = -207$ kJ
$H_2O(l) \rightarrow H_2O(g)\ \Delta H = 44$ kJ

a. 72 kJ
b. -28 kJ
c. -398 kJ
d. 442 kJ

16. The amino acid alanine (ala) dimerizes, forming a dipeptide according the following reaction:

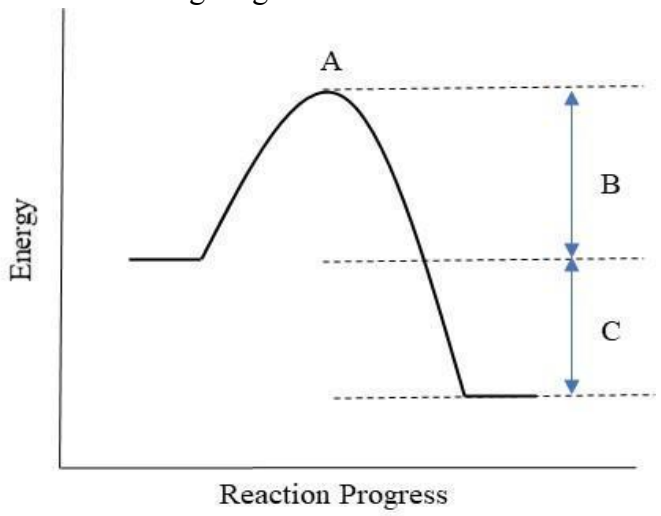
$$2\ \text{Ala} \rightarrow \text{Ala-Ala} + H_2O$$

$\Delta H°$ 298 K	48.2 kJ/mol
$\Delta S°$ 298 K	-30.1 J/K

Which of the following best describes the reaction?

a. $\Delta G° > 0$; the reaction is favorable at 298 K.
b. $\Delta G° < 0$; the reaction is favorable at 298 K.
c. $\Delta G° > 0$; the reaction is unfavorable at 298 K.
d. $\Delta G° < 0$; the reaction is unfavorable at 298 K.

Questions 17 - 19 refer to the following diagram:



17. Which of the following statements best describes the reaction depicted in the diagram?

a. The reaction is exothermic since the energy of the products is lower in energy than the energy of the reactants.
b. The reaction is endothermic since the energy of the product is lower than the energy of the reactants.
c. The reaction is exothermic since the energy of the reactants is lower in energy than the energy of the products.
d. The reaction is endothermic since the energy of the reactants is lower in energy than the energy of the products.

18. Which point on the diagram represents the change in enthalpy ($\Delta H°$) for the reaction?

a. A
b. B
c. C
d. None of the above.

19. Based on the reaction depicted in the diagram, adding a catalyst would_____.

a. decrease the activation energy
b. increase the activation energy
c. decrease the amount of product formed
d. increase the amount of product formed

20. A sample of $^{3}_{1}H$ was found to be 75% decayed after about 24.6 years. Calculate its half-life.

a. 24.6 years
b. 18.4 years
c. 12.3 years
d. 6.15 years

Questions 21 and 22 refer to the following information:

$$A + B \leftrightarrows 2\ C$$

Experiment	[A] mol/L	[B] mol/L	Rate of formation [C] mol/L·sec
1	0.10	0.10	2.5×10^{-4}
2	0.20	0.10	5.0×10^{-4}
3	0.20	0.50	1.25×10^{-2}

21. What is the experimental rate law for the reaction?

a. Rate = $k[A][B]$
b. Rate = $k[A][B]^2$
c. Rate = $k[A][B]^3$
d. Rate = $k[A]^2[B]$

22. Increasing the initial concentration of A fivefold would increase the reaction rate by

a. 5
b. 10
c. 25
d. There is no change in the reaction rate.

23. Which of the following is true regarding a system at equilibrium?

a. The reaction rate of the forward reaction is equal to the reaction rate of the reverse reaction.
b. The product of the concentrations of the reactants is equal to the product of the concentrations of the products.
c. Both statements are true.
d. Neither statement is true.

24. Consider the catalytic decomposition of hydrogen peroxide according to the following reaction

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

The reaction is thought to procced according to the following mechanism:

$$\text{Slow: } H_2O_2(aq) + I^-(aq) \rightarrow H_2O(l) + IO^-(aq)$$
$$\text{Fast: } H_2O_2(aq) + IO^-(aq) \rightarrow H_2O(l) + O_2(g) + I^-(aq)$$

Which component is the catalyst?

a. H_2O_2
b. IO^-
c. I^-
d. O_2

25. Sulfuryl chloride (SO_2Cl_2) decomposes to form sulfur dioxide (SO_2) and chlorine gas (Cl_2) according to the following equation:

$$SO_2Cl_2(g) \leftrightarrows SO_2(g) + Cl_2(g);\ K_c = 0.080 \text{ at } 373\ K$$

A reaction in a 2.00 L reaction vessel at 373 K yields the following mole quantities at a given time, *t*:

0.62 moles of SO_2Cl_2
0.039 moles of SO_2
0.085 moles of Cl_2

Which of the following statements is true regarding the reaction given the quantifies present at the given time, *t*?

a. $K > Q$ and the reaction will proceed in the forward direction
b. $K < Q$ and the reaction will proceed in the forward direction
c. $K > Q$ and the reaction will proceed in the reverse direction
d. $K < Q$ and the reaction will proceed in the reverse direction

26. Consider the following reaction at equilibrium:

$$N_2(g) + 3\ H_2(g) \leftrightarrows 2\ NH_3(g)$$

What will happen if the pressure of the system is increased?

a. The equilibrium will shift to the left producing more reactants
b. The equilibrium will shift to the right producing more product
c. The equilibrium will not shift because the moles of gas on both sides are the same.
d. The reaction will no longer proceed.

27. The pH of a 0.10 M solution of a monoprotic weak acid at 25.0°C is 3.5. What is the value of K_a for the weak acid?

a. 1.0×10^{-5}
b. 1.0×10^{-6}
c. 3.16×10^{-4}
d. 3.16×10^{-7}

28. A buffer solution was made by dissolving sodium dihydrogen phosphate (NaH_2PO_4, $K_a = 6.2 \times 10^{-8}$) and sodium hydrogen phosphate (Na_2HPO_4) together in an aqueous solution. What mole ratio of Na_2HPO_4/NaH_2PO_4 is necessary to maintain a pH around 7.4?

a. 0.90
b. 1.0
c. 1.02
d. 1.6

29. What is the oxidation number of chromium in ammonium dichromate $(NH_4)_2Cr_2O_7$?

a. +3
b. +5
c. +6
d. +7

30. The overall reaction for glycolysis is shown below. What is true of NAD^+ in the reaction?

$$C_6H_{12}O_6 + 2\ NAD^+ + 2\ ADP + 2\ P_i \rightarrow 2\ C_3H_4O_3 + 2\ NADH + 2\ H^+ + 2\ ATP$$

a. NAD^+ is the oxidizing agent and is oxidized to NADH.
b. NAD^+ is the oxidizing agent and is reduced to NADH.
c. NAD^+ is the reducing agent and is oxidized to NADH.
d. NAD^+ is the reducing agent and is reduced to NADH.

31. What is the coefficient for silver metal (Ag(*s*)) when the chemical equation below is balanced?

$$Ag(s) + NO_3^-(aq) + H^+(aq) \rightarrow Ag^+(aq) + NO(g) + H_2O(l)$$

a. 1
b. 2
c. 3
d. 6

32. Calculate the standard cell potential for an electrochemical cell with iron (Fe) and magnesium (Mg) electrodes and correctly identify the cathode given the information below:

$Fe^{3+} + 3\ e^- \rightarrow Fe$ +0.77 V
$Mg^{2+} + 2\ e^- \rightarrow Mg$ -2.37 V

a. +3.14 V, Fe is the cathode
b. -3.14 V, Fe is the cathode
c. +3.14 V, Mg is the cathode
d. -3.14 V, Mg is the cathode

33. The species that contains 26 protons, 30 neutrons and 23 electrons would be represented by the symbol:

a. $^{53}Fe^{3-}$
b. $^{56}Fe^{3-}$
c. $^{53}Fe^{3+}$
d. $^{56}Fe^{3+}$

34. Which of the following represents an impossible set of quantum numbers for an electron in an atom?

a. 3, 3, 3, 1/2
b. 2, 1, -1, -1/2
c. 1, 0, 0, 1/2
d. 5, 4, - 3, 1/2

35. Which of these isoelectronic species has the smallest radius?

a. Br^-
b. Sr^{2+}
c. Rb^+
d. Se^{2-}

36. When Uranium-238 undergoes alpha decay, it produces _____.

a. Thorium-234
b. Plutonium-242
c. Curium-240
d. Radium-236

37. How many bonding pairs and lone pairs of electrons are present in the Lewis structure for formaldehyde, H_2CO?

a. 2 bonding pairs, 4 lone pairs
b. 2 bonding pairs, 2 lone pairs
c. 4 bonding pairs, 2 lone pairs
d. 6 bonding pairs, 0 lone pairs

38. Which molecule is correctly paired with its shape as predicted by VSEPR theory?

a. $AlCl_3$ trigonal pyramidal
b. OH_2 linear
c. ClF_3 trigonal planar
d. SF_6 hexagonal

39. The O–S–O bond angle in SO_2 is approximately _____.

a. 90°
b. 109.5°
c. 120°
d. 180°

40. What is the formal charge on the central oxygen in ozone, O_3?

a. 0
b. +1
c. -1
d. +2

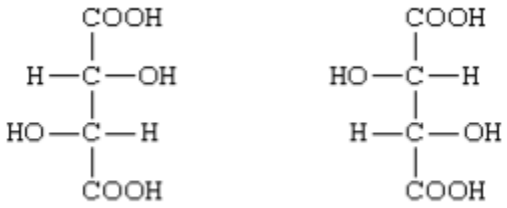
41. The carbon-carbon σ bond in ethylene, C_2H_4, results from the overlap of

a. sp hybrid orbitals.
b. sp^2 hybrid orbitals.
c. sp^3 hybrid orbitals.
d. s atomic orbitals.

42. Which element is not found in common amino acids?

a. hydrogen
b. nitrogen
c. oxygen
d. phosphorus

43. Molecules that are nonsuperimposable mirror images like the ones shown below are



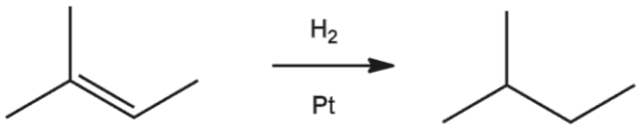
a. the same.
b. diastereomers.
c. enantiomers.
d. resonance structures.

44. A molecule with the formula C_3H_8O may contain which of the following function groups?

I alcohol
II ether
III ketone

a. I
b. II
c. I and II
d. I and III

45. The hydrogenation of an alkene, shown below, is which type of chemical reaction?



a. condensation
b. hydrolysis
c. addition
d. elimination