MAJOR FIELD TEST IN CHEMISTRY
SAMPLE QUESTIONS

The following questions illustrate the range of the test in terms of the abilities measured, the disciplines covered, and the difficulty of the questions posed. They should not, however, be considered representative of the entire scope of the test in either content or difficulty. An answer key follows the questions.

1. Fluorescence at 303 nm is used to measure the amount of tyrosine resulting from hydrolysis of a protein. The fluorescence intensity is found to be a linear function of the concentration. If the intensity for a 1.0 μg/mL standard is 73 and the intensity for the unknown is 62, the concentration of the unknown, in μg/mL, is

   (A) 1.9
   (B) 1.2
   (C) 0.85
   (D) 0.43
   (E) 0.090

2. A mass spectrometer measures which of the following characteristics of molecular ions?

   (A) Mass
   (B) Charge
   (C) Energy
   (D) Weight
   (E) Mass-to-charge ratio

3. A solution containing 0.20 g of a calcium salt is passed through a column containing the hydrogen form of a strong-acid cation-exchange resin. The resulting solution is neutralized with 35.0 mL of 0.10 M sodium hydroxide. What is the number of moles of Ca^{2+} per gram of the calcium salt?

   (A) $\dfrac{(35.0)(0.10)}{(1,000)(0.20)}$
   (B) $\dfrac{(35.0)(0.10)(0.20)}{(1,000)}$
   (C) $\dfrac{(35.0)(0.10)(2)}{(1,000)(0.20)}$
   (D) $\dfrac{(35.0)(0.10)(0.20)}{(1,000)(2)}$
   (E) $\dfrac{(35.0)(0.10)}{(1,000)(2)(0.20)}$

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4. In the analysis of a mixture of two components by gas-liquid chromatography, which of the following gives the best clue as to whether or not the components can be analyzed with any degree of accuracy?

(A) Retention times
(B) Column temperature
(C) Column length
(D) Flow rate of the carrier gas
(E) Injection-port temperature

5. What will be the approximate pH of a buffer prepared by mixing 100 mL of 0.1 M Na_2HPO_4 and 100 mL of 0.1 M NaH_2PO_4? (For H_3PO_4, pK_{a1} = 2.1; pK_{a2} = 6.8; pK_{a3} = 12.5)

(A) 2.1
(B) 4.4
(C) 6.8
(D) 11.2
(E) 12.5

$$2\ OH^-\ (aq) + Cr_2O_7^{2-}\ (aq) \rightarrow 2\ CrO_4^{2-}\ (aq) + H_2O\ (l)$$

6. The dichromate anion, $Cr_2O_7^{2-}$, dissociates almost completely in basic solution, as shown above. If 2.92 g of $K_2Cr_2O_7$ (molar mass 294 g) is dissolved in 500 mL of 1M NaOH, the concentration of CrO_4^{2-} in the solution is closest to

(A) 0.001 M
(B) 0.020 M
(C) 0.040 M
(D) 0.050 M
(E) 0.080 M

Measurement	Pipet X	Pipet Y
1	10.25 mL	9.70 mL
2	9.65 mL	9.69 mL
3	10.10 mL	9.73 mL
4	10.40 mL	9.68 mL
Mean	10.0 mL	9.70 mL
Standard Deviation	0.36	0.02

7. Two students calibrated their 10 mL pipets and obtained the data shown above. Which of the following statements about these data is true?

I. Student X has evidence of a significant indeterminate (random) error.
II. Student X can use the value of 10.00 mL as the volume of pipet X without introducing any significant error (less than 4 parts per thousand) in an analysis
III. Student Y has evidence of a significant indeterminate (random) error.
IV. Student Y can use pipet Y without correction, because the standard deviation is so small.
V. Student Y can use the value of 9.70 mL as the volume of pipet Y without introducing any significant error (less than 4 parts per thousand) in an analysis.

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

8. Of the following elements, which has the lowest first ionization energy?

(A) Au
(B) Cu
(C) Al
(D) Be
(E) Li

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9. Which of the following is the most likely reason that ethanol has a higher normal boiling point (78.5ºC) than dimethyl ether (–23.6ºC)?

   (A) In the liquid phase, ethanol molecules can form hydrogen bonds.
   (B) In the vapor phase, dimethyl ether molecules are attracted to each other by strong hydrogen bonds.
   (C) Dimethyl ether is a more polar molecule than ethanol.
   (D) The intermolecular forces between dimethyl ether molecules are stronger than those between ethanol molecules.
   (E) The molar mass of ethanol is much greater than the molar mass of dimethyl ether.

10. Which of the following hydrogen compounds is NOT a gas at room temperature?

   (A) NaH
   (B) BH_3
   (C) CH_4
   (D) NH_3
   (E) HCl

11. $Ti(H_2O)_6^{3+}$ absorbs light at 500 nm, but TiF_6^{3-} absorbs light at 590 nm. Which of the following explains this difference in absorption?

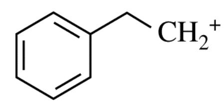
   (A) F^- is a weaker ligand than H_2O, resulting in a smaller crystal field splitting.
   (B) F^- is spherical, while H_2O is bent.
   (C) Coordination complex cations absorb at lower wavelengths than anions.
   (D) Ti changes oxidation state.
   (E) Oxygen is more electronegative than fluorine.

12. The correct name for $K_3[CoCl_2(CN)_4]$ is

   (A) potassium dichlorotetracyanocobalt (II)
   (B) potassium dichlorotetracyanocobaltate (II)
   (C) potassium dichlorotetracyanocobaltate (III)
   (D) tripotassium dichlorotetracyanocobalt (III)
   (E) tripotassium dichlorotetracyanocobaltate (III)

13. What is the molecular geometry of XeF_4?

   (A) Tetrahedral
   (B) Octahedral
   (C) Square planar
   (D) Square pyramidal
   (E) Trigonal bipyramidal



14. The hybridization of the positively-charged carbon atom in the structureeaction intermediate shown above is

   (A) *sp*
   (B) sp^2
   (C) sp^3
   (D) sp^3d
   (E) sp^3d^2

$$NH_3 + BF_3 \rightarrow H_3\overset{+}{N} - \overset{-}{B}F_3$$

15. Which of the following statements about the reaction shown above is true?

   (A) BF_3 acts as a Brønsted acid.
   (B) BF_3 acts as a Lewis acid.
   (C) BF_3 acts as a Brønsted base.
   (D) BF_3 acts as a Lewis base.
   (E) BF_3 acts as both an acid and a base.

16. All of the following acids can be stored in glass bottles EXCEPT

   (A) HI
   (B) $HClO_4$
   (C) H_2SO_4
   (D) HF
   (E) H_3BO_3

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17. Which of the following compounds follows the 18-electron rule?

(A) $Ir(CO)[P(C_6H_5)_3]_2Cl$
(B) $V(CO)_6$
(C) $Ti(\eta^1\text{-}C_5H_5)_2(\eta^5\text{-}C_5H_5)_2$
(D) $Cr(\eta^6\text{-}C_6H_6)_2$
(E) $W(CH_3)_6$

18. The kinetic energy of an electron ejected from a metal surface that is exposed to monochromatic light depends on the all of the following EXCEPT

(A) metal used
(B) frequency of the light used
(C) intensity of the light used
(D) wavelength of the light used
(E) binding energy of the electron in the metal

19. What is the total number of different values that the magnetic quantum number, m_l, can have for the f orbitals with orbital angular momentum quantum number l = 3 ?

(A) 3
(B) 5
(C) 7
(D) 10
(E) 14

20. In a gas sample at room temperature, which of the following states will have the greatest number of molecules occupying states other than the lowest energy state?

(A) Electronic energy state
(B) Rotational energy state
(C) Vibrational energy state
(D) Nuclear spin state
(E) None of the above, since all of the molecules will be in the ground state at room temperature.

21. The balanced equation for the spontaneous cell reaction and the standard cell potential, $E°$, for an electrochemical cell is known at a given temperature. Which of the following thermodynamic functions can be calculated for the reaction from this information?

(A) $\Delta G°$ only
(B) $\Delta H°$ only
(C) $\Delta S°$ only
(D) $\Delta G°$ and $\Delta H°$ only
(E) $\Delta G°$, $\Delta H°$, and $\Delta S°$

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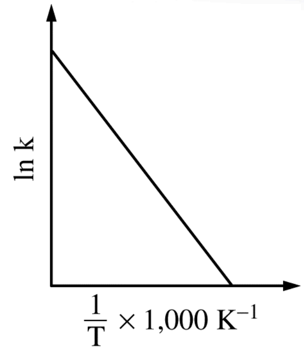
$N_2(g) + 3\ H_2(g) \rightleftarrows 2\ NH_3(g)$ $\Delta H° = -92$ kJ

22. The equilibrium shown above can be driven most completely to the right under which of the following conditions?

    (A) High pressure and low temperature
    (B) High pressure and high temperature
    (C) Low pressure and low temperature
    (D) Low pressure and high temperature
    (E) Moderate pressure with an effective catalyst

23. At sufficiently low temperatures, gaseous ammonia has a molar volume that is less than that predicted by the ideal gas law at certain low pressures, but has a molar volume that is greater than that predicted at certain high pressures. Which of the following is a reasonable explanation for this behavior?

    (A) Attractive forces predominate at these low pressures, and repulsive forces predominate at these high pressures.
    (B) Repulsive forces predominate at these low pressures, and attractive forces predominate at these high pressures.
    (C) Repulsive forces operate over greater distances than attractive forces.
    (D) As the pressure on a gas increases, its temperature increases.
    (E) Hydrogen bonding is not a factor at the critical pressure.



24. A plot of ln k versus l/T, where k is the initial rate constant for a reaction and T is the temperature in Kelvin, is shown above. The slope of the plot is equal to which of the following? (E_a is the activation energy.)

    (A) $2\,E_a$
    (B) $\frac{2\,E_a}{R}$
    (C) $2\,E_a R$
    (D) $\frac{2\,E_a}{RT}$
    (E) $e^{-\frac{E_a}{RT}}$

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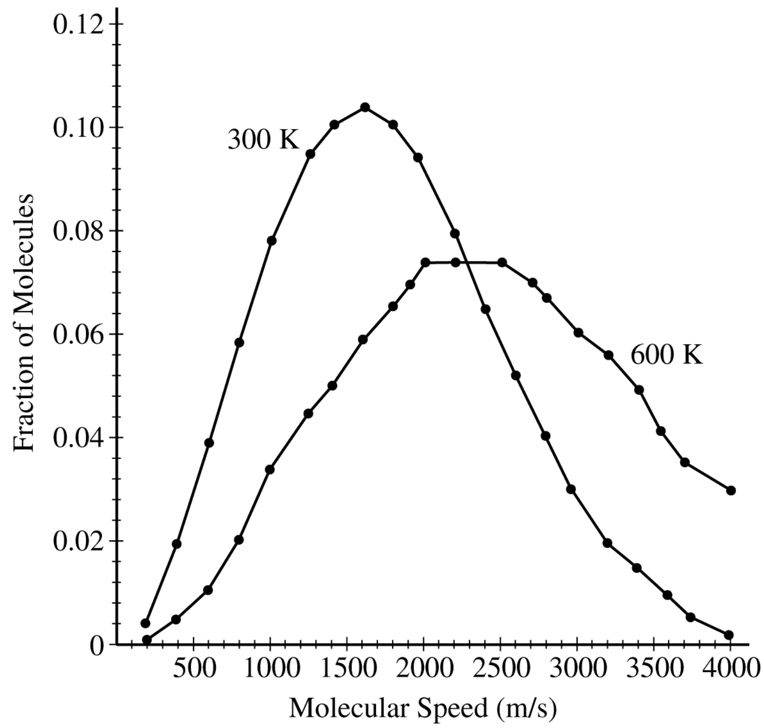

25. The most probable speed (v_{mp}) of an ideal gas molecule can be approximated as

$$v_{mp} = \left(\frac{2RT}{m}\right)^{1/2},$$

where *m* is the mass of a molecule. In the graph above, the curves show the fraction of ideal gas molecules having a given speed for the temperatures 300 K and 600 K, respectively. According to this data, if a curve were plotted for 1,200 K, it would most likely peak at which of the following speeds?

(A) 425 m/s
(B) 850 m/s
(C) 1,700 m/s
(D) 3,400 m/s
(E) 6,800 m/s

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Major Field Tests

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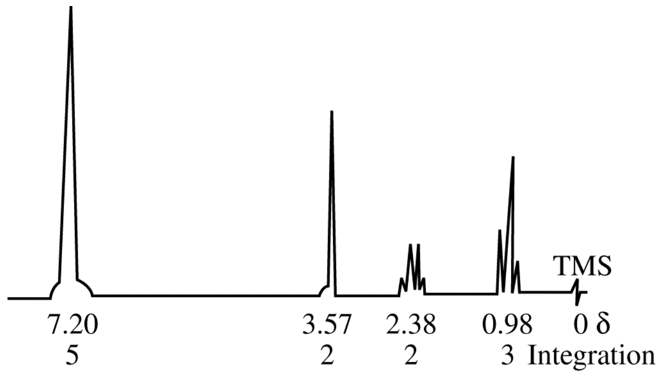
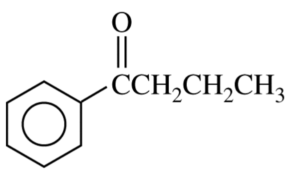
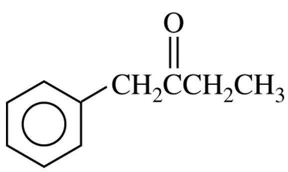
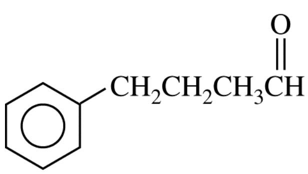
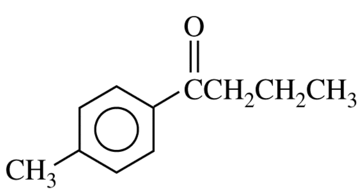


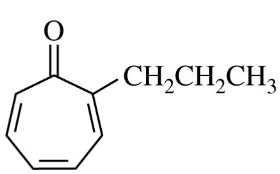
26. An unknown compound $C_{10}H_{12}O$, has the 60-megahertz ^{1}H NMR spectrum shown above. Which of the following could be the unknown compound?

(A) 

(B) 

(C) 

(D) 

(E) 

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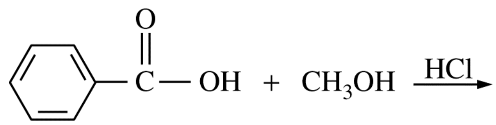
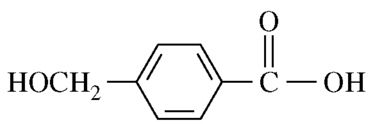
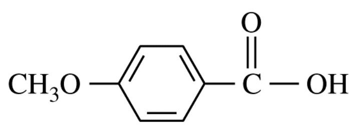
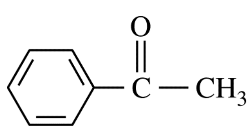
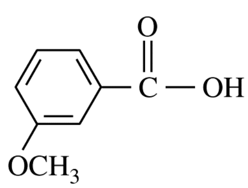


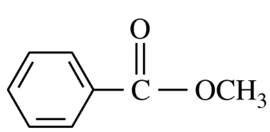
27. Which of the following is the organic product of the reaction shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

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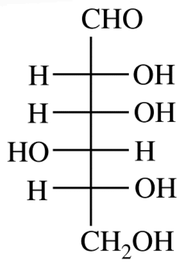


28. At which carbon do all of the D-aldohexoses have the same configuration as D-gulose, shown above?

(A) Carbon 2
(B) Carbon 3
(C) Carbon 4
(D) Carbon 5
(E) Carbon 6

29. Which of the following compounds does NOT react with phenylmagnesium bromide?

(A) $CH_3\overset{\overset{\displaystyle O}{\|}}{C}CH_3$

(B) $O{=}C{=}O$

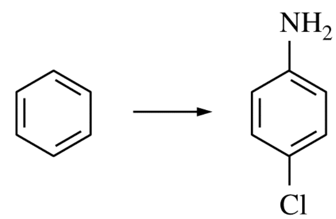
(C) CH_3CH_2OH

(D) $CH_3\overset{\overset{\displaystyle O}{\|}}{C}OH$

(E) $CH_3CH_2OCH_2CH_3$

30. Carbon monoxide is extremely dangerous to living organisms because it

(A) is an irreversible inhibitor of serine proteases such as acetylcholine esterase
(B) competes very effectively with oxygen for binding to the sixth coordination position of Fe^{2+} in heme
(C) causes oxidative DNA damage
(D) is a small nonpolar molecule and therefore acts like a detergent and rips open cell membranes
(E) carbamylates free amino groups in a variety of proteins and enzymes, thus disrupting normal hydrogen bonding



31. Which of the following sets of steps is the best way to accomplish the transformation shown above?

(A) 1. HNO_3, H_2SO_4
2. Fe, HCl
3. HCl

(B) 1. Cl_2, Fe
2. HNO_3, H_2SO_4
3. Fe, HCl

(C) 1. HCl, $NaNO_2$
2. Fe, HCl
3. HNO_3, H_2SO_4

(D) 1. Fe, HCl
2. Cl_2, Fe
3. HNO_3, H_2SO_4

(E) 1. Fuming H_2SO_4
2. Cl_2, Fe
3. HNO_3, H_2SO_4

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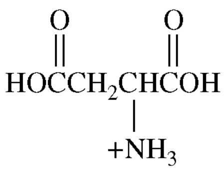
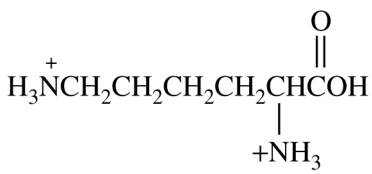
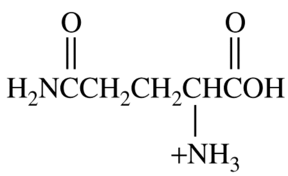
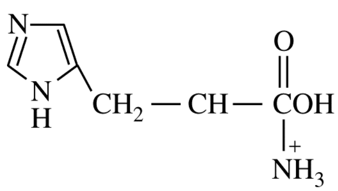
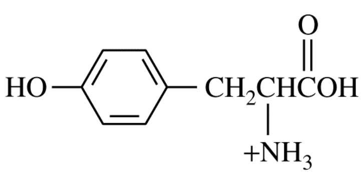
32. Which of the following amino acids has its isoelectric point at the highest pH?

(A)  $pK_a = 1.88, 3.65, 9.60$

(B)  $pK_a = 2.18, 9.12, 10.53$

(C)  $pK_a = 2.17, 9.13$

(D)  $pK_a = 1.82, 6.00, 9.17$

(E)  $pK_a = 2.20, 9.11, 10.07$

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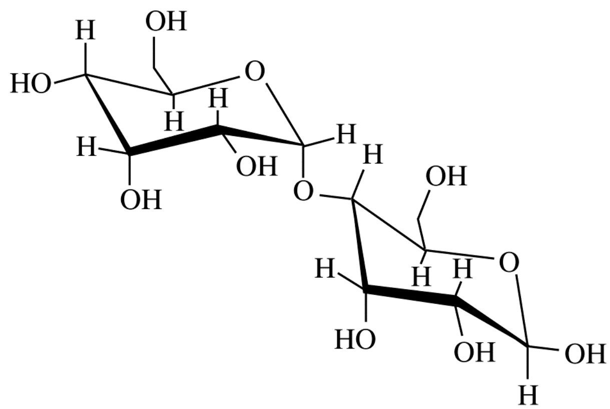
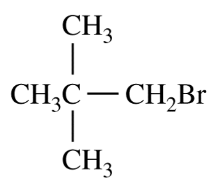
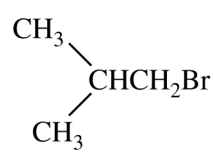


33. The disaccharide shown above contains which of the following glycosidic linkages?

(A) α (1 → 4)
(B) α (1 → 6)
(C) α (2 → 3)
(D) β (1 → 4)
(E) β (1 → 6)

$CH_3CH_2CH_2CH_2Br$  

(1) (2) (3)

34. Of the following, which lists the alkyl bromides shown above in order of decreasing reactivity with sodium iodide in acetone?

(A) 1 > 2 > 3
(B) 1 > 3 > 2
(C) 2 > 3 > 1
(D) 3 > 1 > 2
(E) 3 > 2 > 1

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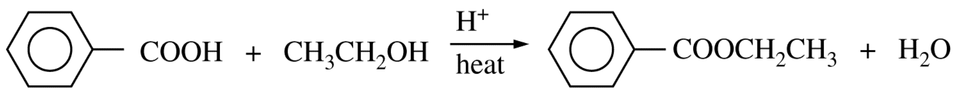
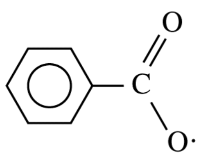
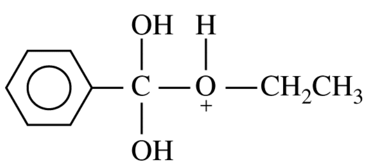


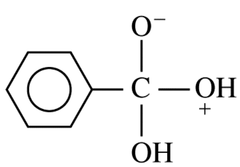
35. Which of the following species is most probably formed during the acid-catalyzed reaction shown above?

(A) $CH_3CH_2\!:^-$

(B) $CH_3CH_2^+$

(C) 

(D) 

(E) 

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Answer Key

1. C	19. C
2. E	20. B
3. E	21. A
4. A	22. A
5. C	23. A
6. C	24. B
7. D	25. D
8. E	26. B
9. A	27. E
10. A	28. D
11. A	29. E
12. C	30. B
13. C	31. B
14. B	32. B
15. B	33. A
16. D	34. B
17. D	35. D
18. C	

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