FORM GR0627

27

GRADUATE RECORD EXAMINATIONS®

CHEMISTRY TEST

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THIS TEST BOOK MUST NOT BE TAKEN FROM THE ROOM.

Material in the tables on pages 10 and 11 may be useful in answering the questions in this examination.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

TABLE OF INFORMATION

Electron rest mass	$m_e = 9.11 \times 10^{-31}$ kg
Proton rest mass	$m_p = 1.672 \times 10^{-27}$ kg
Neutron rest mass	$m_n = 1.675 \times 10^{-27}$ kg
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ C
Bohr radius	$a_0 = 5.29 \times 10^{-11}$ m
Avogadro number	$N_A = 6.02 \times 10^{23}$ per mol
Universal gas constant	$R = 8.314$ J mol^{-1} K^{-1} $= 0.0821$ L • atm mol^{-1} K^{-1} $= 0.08314$ L • bar mol^{-1} K^{-1}
Boltzmann constant	$k = 1.38 \times 10^{-23}$ J/K
Planck constant	$h = 6.63 \times 10^{-34}$ J • s $\hbar = h/2\pi = 1.05 \times 10^{-34}$ J • s
Speed of light	$c = 3.00 \times 10^8$ m/s $= 3.00 \times 10^{10}$ cm/s
1 bar pressure	1 bar $= 1.000$ N m^{-2} $= 1.000 \times 10^5$ Pa $= 0.987$ atm
1 atmosphere pressure	1 atm $= 1.013 \times 10^5$ N m^{-2} $= 1.013 \times 10^5$ Pa $= 1.013$ bar
Faraday constant	$\mathcal{F} = 9.65 \times 10^4$ C/mol
1 atomic mass unit (amu)	1 amu $= 1.66 \times 10^{-27}$ kg
1 electron volt (eV)	1 eV $= 1.602 \times 10^{-19}$ J
Angstrom	1 Å $= 10^{-10}$ m $= 10^{-1}$ nm
Volume of 1 mol of ideal gas at 0° C, 1 atmosphere	$= 22.4$ L

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CHEMISTRY TEST

Time—170 minutes

130 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding space on the answer sheet.

<u>Note:</u> Solutions are aqueous unless otherwise specified.

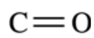
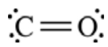
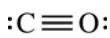
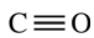
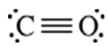
Throughout the test the following symbols have the specified definitions unless otherwise noted.

T	=	temperature	M	=	molar
P	=	pressure	*m*	=	molal
V	=	volume	L	=	liter(s)
S	=	entropy	mL	=	milliliter(s)
H	=	enthalpy	g	=	gram(s)
U	=	internal energy	kg	=	kilogram(s)
G	=	Gibbs energy	m	=	meter(s)
A	=	Helmholtz energy	nm	=	nanometer(s)
R	=	gas constant	atm	=	atmosphere(s)
n	=	number of moles	J	=	joule(s)
s	=	seconds	kJ	=	kilojoule(s)
mol	=	mole(s)	ppm	=	parts per million
C	=	coulomb(s)	Pa	=	Pascal(s)
			V	=	volt(s)

1. Of the following, which element has the highest first ionization energy?

   (A) As
   (B) Ge
   (C) Ga
   (D) Rb
   (E) Sr

2. Which of the following is the most acceptable Lewis electron dot structure for carbon monoxide?

   (A) 
   (B) 
   (C) 
   (D) 
   (E) 

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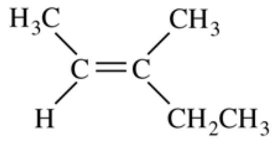
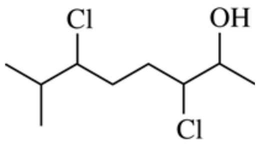


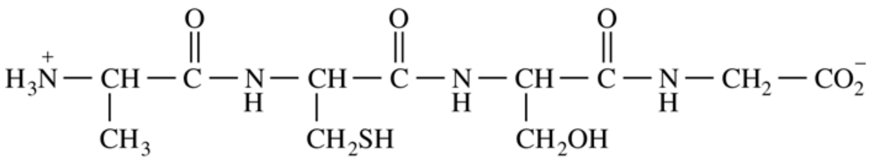
3. What is the correct IUPAC name for the compound shown above?

   (A) *trans*-3-methyl-3-pentene
   (B) *cis*-2-ethyl-2-butene
   (C) (*E*)-3-methyl-2-pentene
   (D) (*Z*)-3-methyl-2-pentene
   (E) (*Z*)-2-ethyl-2-butene



4. What is the total number of stereoisomers possible for the compound shown above?

   (A) 3
   (B) 4
   (C) 6
   (D) 8
   (E) 16



5. The total number of peptide bonds in the structure shown above is

   (A) 1
   (B) 2
   (C) 3
   (D) 4
   (E) 5

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6. A 0.10 L solution of $Cl^-(aq)$ is titrated with 1.0×10^{-3} M $Ag^+(aq)$. The end point is reached when 0.025 L of the Ag^+ solution has been added. What was the concentration of Cl^- in the original solution?

(A) 1.0×10^{-4} M
(B) 2.5×10^{-4} M
(C) 4.0×10^{-4} M
(D) 8.0×10^{-4} M
(E) 1.0×10^{-3} M

$$C(s) + CO_2(g) \rightleftharpoons 2\,CO(g)$$

7. ΔH for the reaction shown above is greater than zero. Assuming ΔH is independent of temperature, which of the following statements about the percent yield of $CO(g)$ is true?

(A) It increases as the amount of $C(s)$ increases.
(B) It increases as the temperature increases.
(C) It decreases as the temperature increases.
(D) It doubles when the initial partial pressure of CO_2 is doubled.
(E) It increases when the total pressure of the reaction system increases.

[A]	[B]	Initial Rate
0.50 M	0.50 M	10 M s^{-1}
0.50 M	1.00 M	20 M s^{-1}
0.25 M	0.50 M	5 M s^{-1}
1.00 M	1.00 M	40 M s^{-1}

8. The initial rates given above were determined for the reaction $A + 2\,B \rightarrow AB_2$. What is the overall rate law for this reaction?

(A) Rate = $k[A]^2[B]^2$
(B) Rate = $k[A]^2[B]$
(C) Rate = $k[A][B]^2$
(D) Rate = $k[A][B]$
(E) Rate = k

9. Assuming that air is approximately 80 percent nitrogen and 20 percent oxygen by volume, which of the following is closest to the density of air at 0°C and 1 atmosphere?

(A) 0.01 g/L
(B) 0.1 g/L
(C) 1 g/L
(D) 10 g/L
(E) 100 g/L

$$H-C\equiv C-H$$

10. How many π bonds are there in acetylene, shown above?

(A) 1
(B) 2
(C) 3
(D) 4
(E) 5

1. $CHF_2CH_2CH_2CO_2H$

2. $CH_3CF_2CH_2CO_2H$

3. $CH_3CH_2CF_2CO_2H$

4. $CH_3CH_2CH_2CO_2H$

11. In which of the following are the carboxylic acids shown above listed in order of decreasing acidity, from most acidic to least acidic?

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

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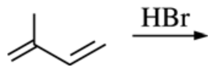
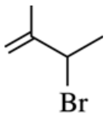
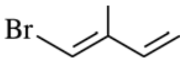
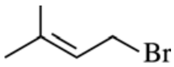
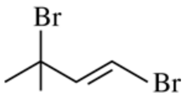


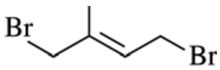
12. Which of the following is a 1,4-addition product of the reaction shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

13. Which of the following is a weak Brønsted-Lowry acid?

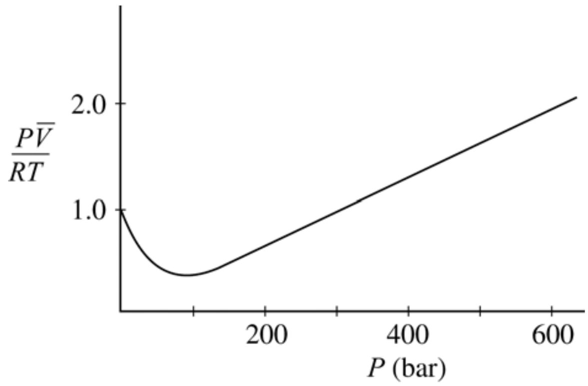
(A) HCl
(B) HNO_3
(C) H_2SO_4
(D) H_2S
(E) $HClO_4$

14. Which of the following correctly lists the species in order of increasing radius from smallest to largest?

(A) $K^+ < Ar < Cl^-$
(B) $Ar < Cl^- < K^+$
(C) $K^+ < Cl^- < Ar$
(D) $Cl^- < Ar < K^+$
(E) $Ar < K^+ < Cl^-$

15. The half-life of ^{14}C is 5,730 years. All of the following are true for the method of carbon dating EXCEPT:

(A) ^{14}C undergoes β-decay to produce ^{14}N.
(B) The ^{14}C content of an organism decreases after it dies.
(C) The $^{14}C/^{12}C$ ratio is the same in living terrestrial organisms as in the atmosphere.
(D) The $^{14}C/^{12}C$ ratio can be used to date a sample from a dead organism.
(E) Carbon dating is equally useful for samples that are millions of years old as for samples that are about 10,000 years old.



16. The curve shown above illustrates the $P\overline{V}$ behavior of a real gas, where $\overline{V}$ is the molar volume. According to the van der Waals model for nonideal gas behavior, the values of $P\overline{V}/RT$ greater than 1.0 at high pressures are due to

(A) the effects of increased rate of collision of the molecules with the walls of the container
(B) the effects of dissociation of individual gas molecules
(C) the effects of the volume occupied by the molecules themselves
(D) the effects of forces of attraction between molecules
(E) ideal gas behavior in this pressure region

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$$O_3(g) \rightarrow \frac{3}{2}O_2(g)$$

17. For the reaction shown above at 298 K, $\Delta G° = -163$ kJ/mol. What is the value of the equilibrium constant, K_P, for this reaction?

(A) $K_P > 1.0$
(B) $K_P = 1.0$
(C) $0.0 < K_P < 1.0$
(D) $K_P = 0.0$
(E) $K_P < 0.0$

18. In an isolated hydrogen atom, the $2p_x$ orbital has the same principal quantum number, n, as which of the following orbitals?

I. $2s$
II. $2p_z$
III. $3p_x$

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

19. Which of the following is NOT an allotrope of carbon?

(A) Diamond
(B) Graphite
(C) C_{60}
(D) C_{70}
(E) C_2^{2-}

20. Of the following covalent bonds, which has the greatest bond dissociation energy?

(A) $C{=}C$
(B) $O{=}O$
(C) $C{=}Si$
(D) $Si{\equiv}Si$
(E) $C{\equiv}O$

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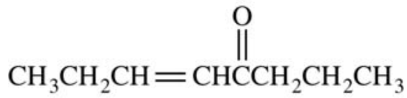
21. Assuming complete dissociation, which of the following is NOT true about a 1.00 M $Mg(NO_3)_2$ solution? (Molar masses: Mg = 24.30 g; NO_3^- = 62.01 g; $Mg(NO_3)_2$ = 148.31 g)

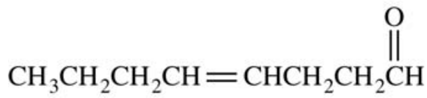
(A) The concentration of nitrate ions is 2.00 mol L^{-1}.
(B) The total concentration of ions is 3.00 mol L^{-1}.
(C) The total mass of solute in 1.00 L of this solution is 148 g.
(D) There are 2.43 g of Mg^{2+} in 100 mL of this solution.
(E) There are 6.20 g of NO_3^- in 100 mL of this solution.

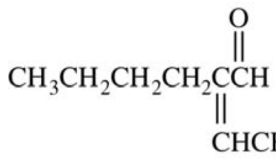
22. A 499 mg sample of $CuSO_4{\cdot}nH_2O$ is heated to drive off the waters of hydration and then reweighed to give a final mass of 319 mg. Given that the sample contains 2.0 mmol of Cu, what is the average number of waters of hydration, n, in $CuSO_4{\cdot}nH_2O$?

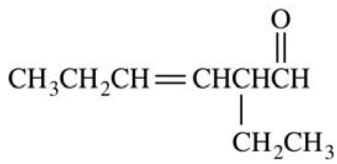
(A) 2.0
(B) 5.0
(C) 10.
(D) 18
(E) 20.

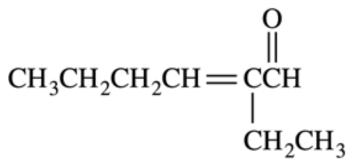
23. Which of the following is the aldol condensation product of butanal ($CH_3CH_2CH_2CHO$) ?

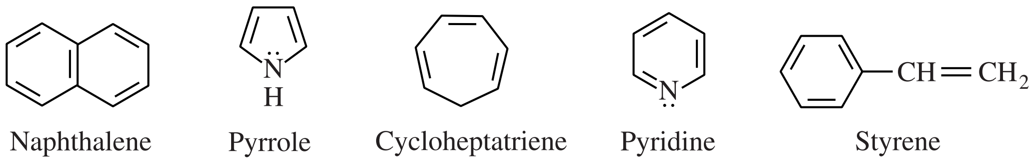
(A)


(B)


(C)


(D)


(E)




24. Which of the following statements correctly applies Hückel's rule to the molecules shown above?

(A) Naphthalene is not monocyclic; therefore it cannot be aromatic.
(B) Pyrrole is not a hydrocarbon; therefore it cannot be aromatic.
(C) Cycloheptatriene is not completely conjugated; therefore it cannot be aromatic.
(D) Pyridine is weakly basic; therefore it cannot be aromatic.
(E) Styrene has 8 π electrons; therefore it cannot be aromatic.

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25. When 1.0 kJ of heat is added to 5.0 L of an ideal gas, the gas expands against a constant external pressure of 1.0 bar to a final volume of 8.0 L. What is the change in internal energy, ΔU, for the gas? (1.0 L•bar = 0.10 kJ)

(A) 0.30 kJ
(B) 0.70 kJ
(C) 1.0 kJ
(D) 1.3 kJ
(E) 1.8 kJ

26. Which of the following must be true for adiabatic processes?

(A) $C_V = C_P$
(B) $\Delta H = 0$
(C) $\Delta U = 0$
(D) $\Delta S = 0$
(E) $q = 0$

27. At 37°C, the dissociation constant, K_w, of water is 2.5×10^{-14} ($pK_w = 13.6$). What is the pH of a 1.0×10^{-5} M NaOH solution at 37°C ?

(A) 4.6
(B) 5.0
(C) 8.6
(D) 9.0
(E) 13.6

$$\_\_\, H^+ + \_\_\, IO_3^- + \_\_\, I^- \rightarrow \_\_\, I_2 + \_\_\, H_2O$$

28. The reaction shown above is not balanced. If the reaction is balanced using the smallest whole number coefficients possible, the coefficient for I^- will be

(A) 1
(B) 2
(C) 3
(D) 5
(E) 10

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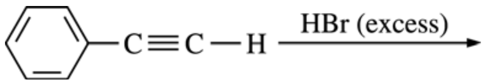
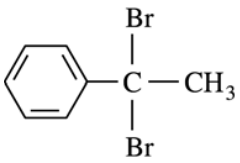
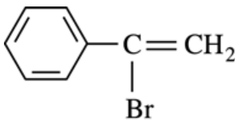
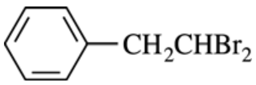
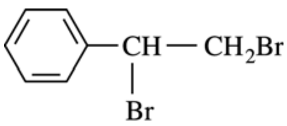


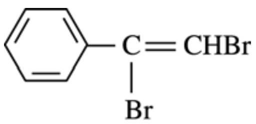
29. Which of the following is the major product of the reaction shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

$$\underset{\displaystyle |\atop \displaystyle Br}{CH_3CH_2CHCH_3} \xrightarrow{CH_3OH}$$

30. The reaction of 2-bromobutane with methanol, as shown above, yields which of the following as the major product?

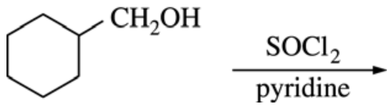
(A) $CH_3CH_2CH(OH)CH_3$

(B) $CH_3CH_2CH(OCH_3)CH_3$

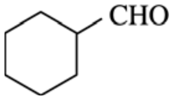
(C) $CH_3CH_2C(OCH_3)_2CH_3$

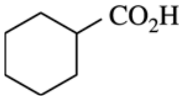
(D) $CH_3CH_2CH{=}CH_2$

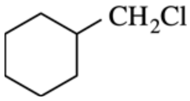
(E) $CH_3C{\equiv}CCH_3$

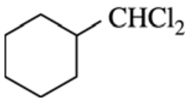


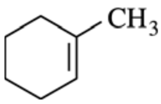
31. Which of the following is the major organic product of the reaction shown above?

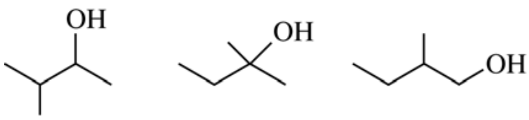
(A) 

(B) 

(C) 

(D) 

(E) 



1 2 3

32. In which of the following are the compounds shown above listed in order of increasing reactivity to acid-catalyzed dehydration?

(A) $1 < 2 < 3$
(B) $1 < 3 < 2$
(C) $2 < 3 < 1$
(D) $3 < 1 < 2$
(E) $3 < 2 < 1$

33. Two cylinders, one containing 1 mole of C_4H_{10} gas at 1 atm and the other containing 1 mole of CH_4 gas at 1 atm, are at 288 K. If each gas absorbs 100 J of heat under conditions of constant volume, which of the following is true?

(A) The temperature of the CH_4 increases more than the temperature of the C_4H_{10}.
(B) The internal energy of both the CH_4 and the C_4H_{10} decreases.
(C) The heat capacity of the C_4H_{10} is less than the heat capacity of the CH_4.
(D) The entropy of both the CH_4 and the C_4H_{10} decreases.
(E) The heat transferred to the C_4H_{10} is greater than the heat transferred to the CH_4.

34. Which of the following statements is true about a pure substance above its critical point?

(A) One fluid phase is present.
(B) Solid, liquid, and gas are in equilibrium.
(C) Only liquid and gas are in equilibrium.
(D) A liquid forms.
(E) A solid forms.

$$\int_{-\infty}^{+\infty} \psi_1^*(x)\,\psi_2(x)\,dx = 0$$

35. If two wavefunctions $\psi_1(x)$ and $\psi_2(x)$ satisfy the condition given above, the two wavefunctions are

(A) orthogonal
(B) degenerate
(C) normalized
(D) continuous
(E) symmetrical

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$$\hat{A} = \frac{d^2}{dx^2} \qquad \psi = \sin kx$$

36. For the equation $\hat{A}\psi = a\psi$, where $\hat{A}$ and ψ are shown above, all of the following are true EXCEPT:

(A) ψ is an eigenfunction of $\hat{A}$.
(B) a is an eigenvalue.
(C) a is an observable.
(D) $\hat{A}$ is an operator corresponding to the observable.
(E) $\hat{A}$ is an eigenfunction of a.

37. At standard temperature and pressure, all of the following compounds exist in the gas state EXCEPT

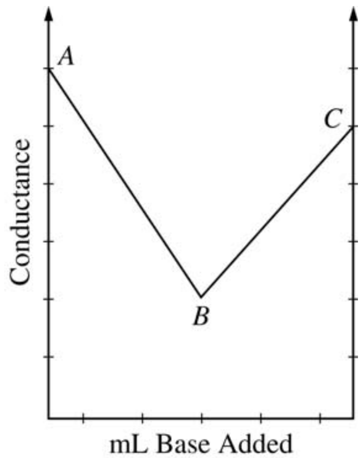
(A) HCl
(B) HBr
(C) NH_3
(D) BH_3
(E) LiH

38. The electron configuration of Co in $[Co(NH_3)_6]Cl_3$ is

(A) [Ar] $4s^2 3d^7$
(B) [Ar] $4s^2 3d^4$
(C) [Ar] $3d^9$
(D) [Ar] $3d^7$
(E) [Ar] $3d^6$

39. A 0.600 g sample of a pure, weak diprotic acid gives end points at 20.0 mL and 40.0 mL when it is titrated with 0.100 M NaOH. What is the molar mass of the weak acid?

(A) 120 g
(B) 150 g
(C) 180 g
(D) 300 g
(E) 450 g



40. The figure shown above is a plot of conductance data obtained during the titration of HCl with a standard solution of NaOH. Which of the following statements about the results is NOT true?

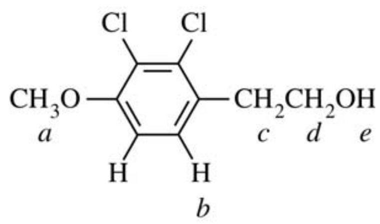
(A) Point B is the end point of the titration.
(B) $|\text{slope } AB| > |\text{slope } BC|$
(C) The measured conductance increases after point B because the overall concentration of ions increases.
(D) Na^+ must have a higher equivalent conductance than H_3O^+.
(E) Segment BC represents the conductance due to ions from NaCl and NaOH in solution.

41. The molecular geometry of IF_5 is

(A) square pyramidal
(B) trigonal planar
(C) bent
(D) linear
(E) octahedral

42. At a given temperature, the vapor pressure of SiF_4 is significantly higher than that of SF_4. The major physical basis for the difference in vapor pressure is that SiF_4 and SF_4 have different

(A) dipole moments
(B) molar masses
(C) ionization energies
(D) electron affinities
(E) magnetic susceptibilities



43. Which of the protons indicated will be observed as a doublet in the ^{1}H NMR spectrum of the molecule shown above?

    (A) *a*
    (B) *b*
    (C) *c*
    (D) *d*
    (E) *e*

$$CH_3CH_2C{\equiv}CCH_2CH_3 \xrightarrow[\text{liquid } NH_3]{Na}$$

44. Which of the following is the major product of the reaction shown above?

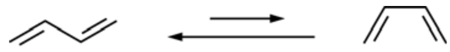
    (A) $CH_3CH_2CH_2CH_2C{\equiv}CNa$

    (B) $CH_3CH_2CH_2CH_2CH_2CH_3$

    (C) *cis*-$CH_3CH_2CH{=}CHCH_2CH_3$

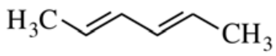
    (D) *trans*-$CH_3CH_2CH{=}CHCH_2CH_3$

    (E) $CH_3CH_2CH{=}\underset{\overset{|}{NH_2}}{C}CH_2CH_3$

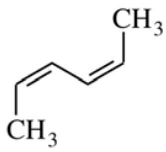


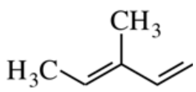
s-trans *s*-cis

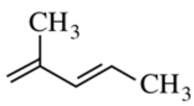
45. Acyclic conjugated dienes may exist in two conformations, as shown above. Based on differences in steric strain, which of the following dienes has the greatest preference for the *s*-trans conformation?

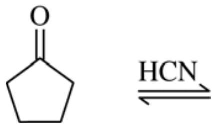
    (A) 

    (B) 

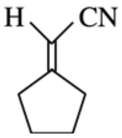
    (C) 

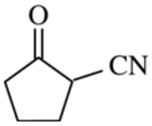
    (D) 

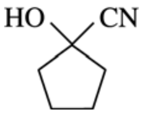
    (E) 



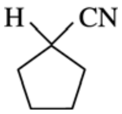
46. Which of the following substances is in equilibrium with cyclopentanone and HCN shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

47. All of the following elements have at least one isotope that is not radioactive EXCEPT

(A) O
(B) Pb
(C) Sn
(D) No
(E) He

48. Based on the molecular orbital model, which of the following is the number of unpaired electrons and the bond order for the superoxide ion, O_2^- ?

	Unpaired Electrons	Bond Order
(A)	1	0.5
(B)	1	1.5
(C)	1	2.5
(D)	2	1
(E)	2	2

49. For a system at thermal equilibrium, which of the following is the Boltzmann distribution expression for the probability, p_i, that a single molecule is in the ith energy state with energy ε_i?

(A) $p_i = \varepsilon_i / kT$

(B) $p_i = 1 - e^{-\varepsilon_i / kT}$

(C) $p_i = \left(\sum_{i=0}^{\infty} e^{-\varepsilon_i / kT}\right) - e^{-\varepsilon_i / kT}$

(D) $p_i = \left(e^{-\varepsilon_i / kT}\right)^{N_i}$

(E) $p_i = \dfrac{e^{-\varepsilon_i / kT}}{\left(\sum_{i=0}^{\infty} e^{-\varepsilon_i / kT}\right)}$

50. Which of the following expressions involving fugacity, f, is correct as $P \to 0$?

(A) $f = P$

(B) $f = \dfrac{1}{P}$

(C) $f = 1$

(D) $f = \dfrac{1}{V}$

(E) $f = V$

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51. Sodium acetate spontaneously crystallizes out of a supersaturated solution on standing or on the addition of a seed crystal. Which of the following is true for the thermodynamic quantities of this system for this process?

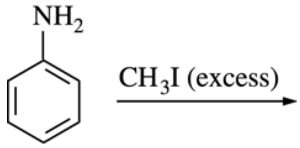
(A) $\Delta S < 0,\ \Delta H < 0$
(B) $\Delta S < 0,\ \Delta G > 0$
(C) $\Delta S > 0,\ \Delta H > 0$
(D) $\Delta S > 0,\ \Delta G < 0$
(E) $\Delta G < 0,\ \Delta H > 0$

52. If ideal gas behavior is assumed, for which of the following reactions does ΔH equal ΔU ?

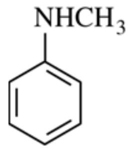
(A) $N_2O_4(g) \rightarrow 2\ NO_2(g)$
(B) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$
(C) $SO_2(g) + \frac{1}{2}\ O_2(g) \rightarrow SO_3(g)$
(D) $Br_2(l) + 3\ Cl_2(g) \rightarrow 2\ BrCl_3(g)$
(E) $Cl_2(g) + F_2(g) \rightarrow 2\ ClF(g)$

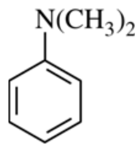
53. $PbF_2(s)$, which is slightly soluble in water, is dissolved in water to form a saturated solution in equilibrium with solid PbF_2. Which of the following will cause additional $PbF_2(s)$ to dissolve?

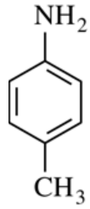
(A) Adding HNO_3
(B) Adding $Pb(NO_3)_2$
(C) Adding a seed crystal
(D) Adding solid PbF_2
(E) Evaporating some of the water to decrease the volume of solution

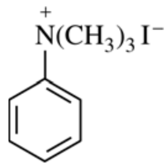


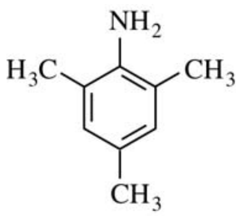
54. Which of the following is the major product of the reaction shown above?

(A)


(B)


(C)


(D)


(E)


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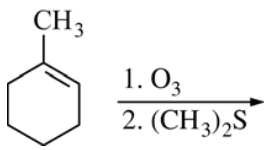


55. Which of the following is the product of the reaction shown above?

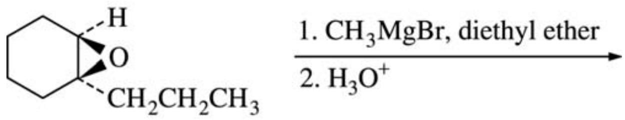
(A) $CH_3\overset{O}{\overset{\|}{C}}CH_2CH_2CH_2\overset{O}{\overset{\|}{C}}CH_3$

(B) $CH_3\overset{O}{\overset{\|}{C}}CH_2CH_2CH_2CH_2\overset{O}{\overset{\|}{C}}H$

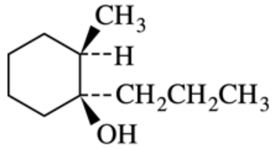
(C) $H\overset{O}{\overset{\|}{C}}\underset{CH_3}{\underset{|}{C}}HCH_2CH_2CH_2\overset{O}{\overset{\|}{C}}H$

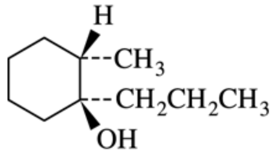
(D) $CH_3\underset{OH}{\underset{|}{C}}HCH_2CH_2CH_2CH_2CH_2OH$

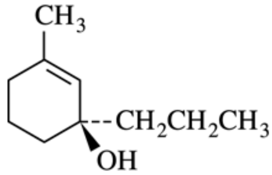
(E) $HOCH_2\underset{CH_3}{\underset{|}{C}}HCH_2CH_2CH_2CH_2OH$

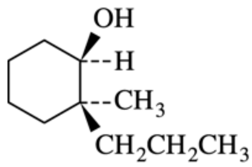


56. Which of the following is the major product of the reaction shown above?

(A)


(B)


(C)


(D)


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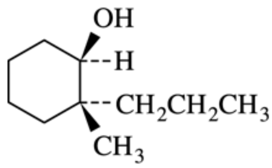

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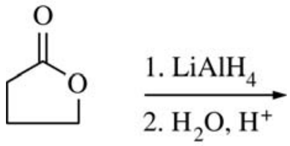

57. Which of the following is the major organic product of the reaction shown above?

(A) $CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}OH$

(B) $HOCH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}OH$

(C) $HOCH_2CH_2CH_2CH_2OH$

(D) $CH_3CH_2CH_2CH_2OH$

(E) $H\overset{\overset{\displaystyle O}{\|}}{C}OCH_2CH_2CH_3$

$$\left(\frac{\partial U}{\partial V}\right)_T = -P + T\left(\frac{\partial P}{\partial T}\right)_V$$

58. Given the expression above, what is the value of $\left(\frac{\partial U}{\partial V}\right)_T$ for an ideal gas undergoing isothermal expansion? ($PV = nRT$ for an ideal gas.)

(A) $-P + \frac{nR}{V}$
(B) nR
(C) $-P$
(D) 1
(E) 0

59. The heat of fusion of ice is 333.5 J/g. The entropy change for the water when freezing 5.0 g of water at 0°C and 1 atm pressure is

(A) 6.1 J/K
(B) 1.2 J/K
(C) 0
(D) −1.2 J/K
(E) −6.1 J/K

$$\text{rate} = \frac{V[\text{S}]}{K_m + [\text{S}]}$$

60. Many enzyme reactions follow the Michaelis-Menten rate law shown above, where V and K_m are constants and $[\text{S}]$ is the concentration of substrate that is undergoing a catalyzed reaction. When $[\text{S}] >> K_m$, what is the apparent order of the reaction?

(A) Zero order
(B) One-half order
(C) First order
(D) Second order
(E) Third order

61. If for $Ni(OH)_2$ the K_{sp} is 8.0×10^{-18}, then the expression used to calculate the molar solubility S of $Ni(OH)_2$ is

(A) $S = \sqrt[3]{2.0 \times 10^{-18}}$
(B) $S = \sqrt[3]{4.0 \times 10^{-18}}$
(C) $S = \sqrt[3]{8.0 \times 10^{-18}}$
(D) $S = \sqrt[3]{5.0 \times 10^{-19}}$
(E) $S = \sqrt[3]{1.5 \times 10^{-19}}$

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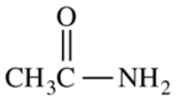
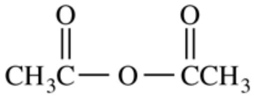
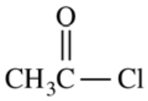
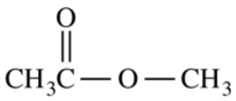
62. Of the following compounds, which reacts most rapidly with water?

(A) 

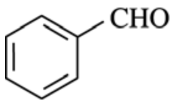
(B) 

(C) 

(D) 

(E) $CH_3C\equiv N$

63. Which of the following compounds will react with $(CH_3)_2NH$ to form an enamine?

(A) CH_3CH_2CHO
(B) $CH_3CH_2CO_2H$
(C) $CH_3CH_2CH_2OH$
(D) 

(E) $H_2C=O$

64. All of the following reactions are examples of the Lewis definition of acid-base behavior EXCEPT

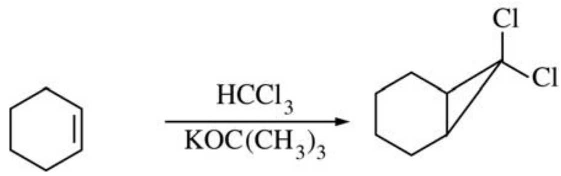
(A) $FeCl_3 + Cl^- \rightarrow [FeCl_4]^-$
(B) $I_2 + I^- \rightarrow I_3^-$
(C) $SO_3 + H_2O \rightarrow H^+ + HSO_4^-$
(D) $Zn(s) + I_3^- \rightarrow Zn^{2+} + 3I^-$
(E) $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

65. Of the following, which is the weakest oxidizing agent?

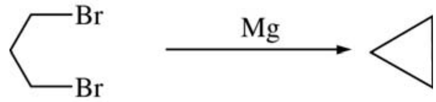
(A) $MnO_4^-(aq)$
(B) $H_2O_2(aq)$
(C) $I_2(s)$
(D) $H^+(aq)$
(E) $Mg(s)$

66. Which of the following reactions proceeds via a carbene (or carbenoid) intermediate?

(A)



(B)



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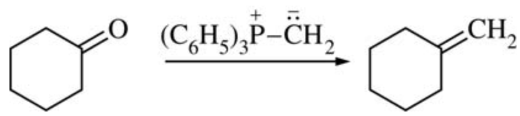

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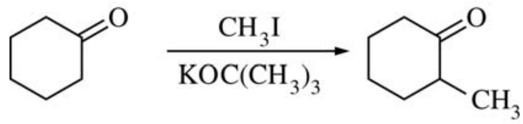
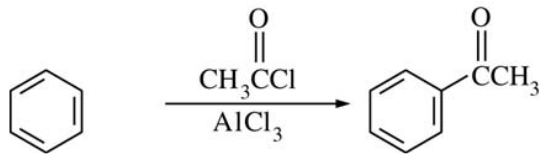


(E)



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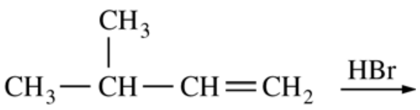
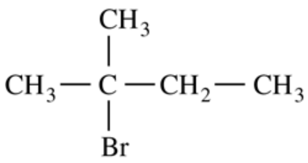
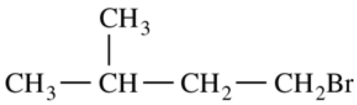


67. Which of the following is the major carbocation rearrangement product of the reaction shown above?

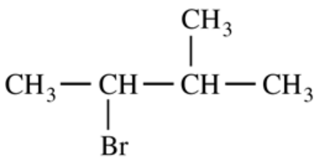
(A)



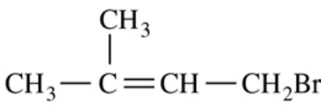
(B)



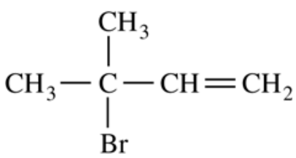
(C)



(D)



(E)



	Standard	Sample
[Benzene], μg/mL	50	-
[Ethylbenzene], μg/mL	10	10
Benzene peak area, mV•s	2,500	2,500
Ethylbenzene peak area, mV•s	1,000	500

68. The table above shows chromatographic data for the analysis of benzene using an ethylbenzene internal standard. What is the benzene concentration of the sample in μg/mL ?

(A) 10
(B) 25
(C) 80
(D) 100
(E) 250

69. A high-resolution infrared absorption spectrum of a heteronuclear diatomic molecule is shown above. Information about which of the following kinds of energy levels of the diatomic molecule can be obtained from this spectrum?

I. Electronic
II. Vibrational
III. Rotational

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

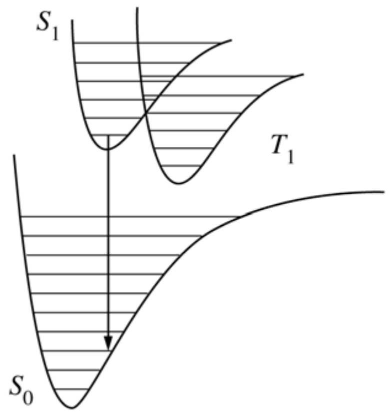
$$\Delta E = hcR_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

70. The ionization energy of a ground state H atom is 13.6 eV. Given the equation shown above, how much energy is needed to excite an electron in an H atom from a state with quantum number $n = 1$ to a state with $n = 2$?

(A) (1/8) 13.6 eV
(B) (1/4) 13.6 eV
(C) (1/2) 13.6 eV
(D) (3/4) 13.6 eV
(E) 13.6 eV

71. All of the following are true about lasers EXCEPT:

(A) The light does not diverge significantly.
(B) The light is emitted only in pulses.
(C) The light waves are in phase.
(D) The light is essentially all the same wavelength.
(E) The light is essentially all the same frequency.



72. Consider the ground electronic state S_0, the excited singlet state S_1, and the triplet state T_1 of a molecule, shown above. The $S_1 \rightarrow S_0$ transition corresponds to

(A) a forbidden transition
(B) fluorescence
(C) phosphorescence
(D) photoionization
(E) vibrational relaxation

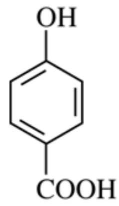
73. Graphite reacts with potassium to produce a compound with the empirical formula KC_8. Of the following, which is the best description of this compound's structure?

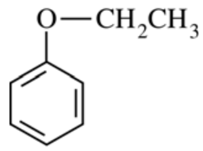
(A) K^+ ions close-packed with polyhedral C_8^- ions
(B) K^- ions close-packed with polyhedral C_8^+ ions
(C) K^+ ions packed with C_2^{2-} ions
(D) Negatively charged hexagonal carbon layers with intercalated K^+ ions between them
(E) An expanded diamond lattice with K^+ ions in the tetrahedral holes

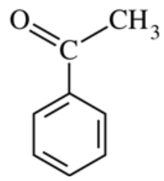
74. The experimental technique most suited for the determination of the three-dimensional structure of a crystalline solid is

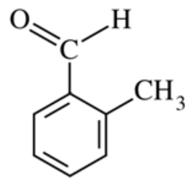
(A) UV-visible spectroscopy
(B) X-ray diffraction
(C) measurement of colligative properties
(D) polarimetry
(E) Fourier transform mass spectrometry

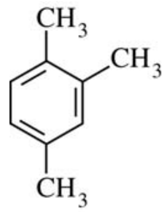
75. In a particular TLC separation, the stationary phase is a C2 plate (= $-CH_2CH_3$), and the mobile phase is 60% methanol:40% water (*v*:*v*). Of the following compounds, which will likely travel the greatest distance during the analysis?

(A) 

(B) 

(C) 

(D) 

(E) 

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76. Which of the following statements about sulfur dioxide is true?

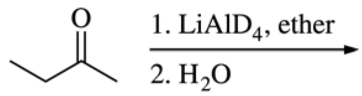
(A) It forms an S–S bonded dimer in condensed phases.
(B) It is the anhydride of sulfuric acid, H_2SO_4.
(C) It plays an important physiological role in the transmission of nerve impulses.
(D) Its O–S–O angle is 180°.
(E) It is a product of the combustion of fossil fuels that contain sulfur.

77. Which of the following statements about polonium, the heaviest Group 16 element, is NOT true?

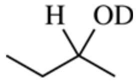
(A) Polonium is the least metallic of the Group 16 elements.
(B) Polonium has the lowest ionization energy of the Group 16 elements.
(C) Polonium atoms are the largest of the Group 16 elements.
(D) Polonium is expected to be a solid at room temperature and pressure.
(E) When ^{209}Po undergoes alpha decay, it forms ^{205}Pb.

78. In their metallic form, elements from which of the following groups are usually effective hydrogenation catalysts?

(A) Alkaline earth metals
(B) Platinum metals
(C) Halogens
(D) Actinides
(E) Group 12 metals

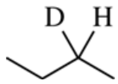


79. Which of the following is the product of the reaction shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

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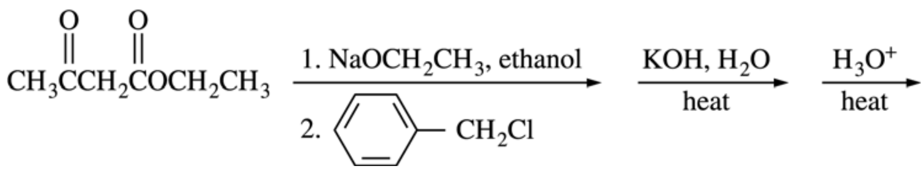
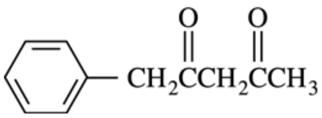
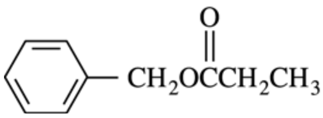


80. Which of the following is the product of the series of reactions shown above?

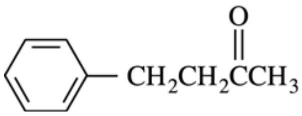
(A)



(B)



(C)



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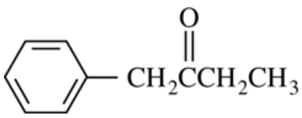

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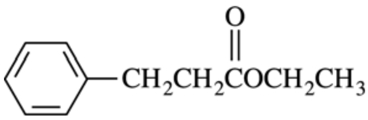
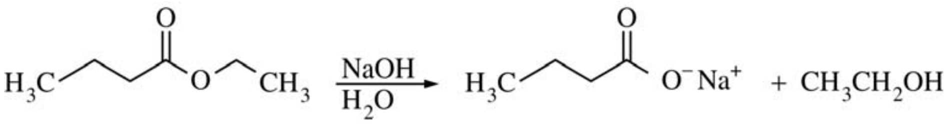
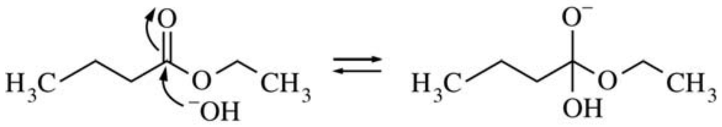


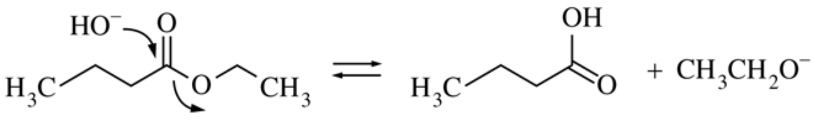


81. Which of the following is a step in the mechanism of the hydrolysis of the ester shown above?

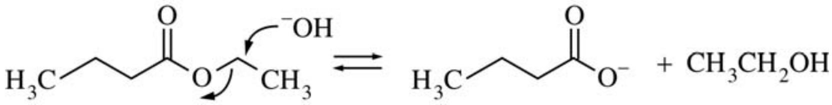
(A)



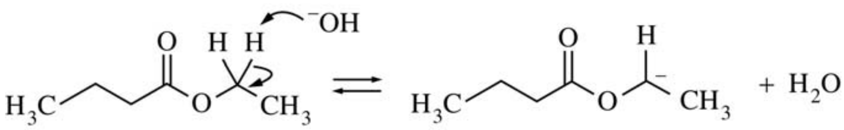
(B)



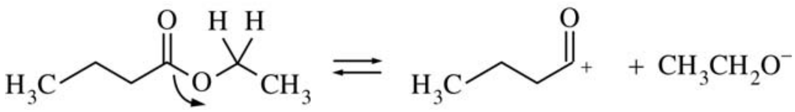
(C)



(D)



(E)



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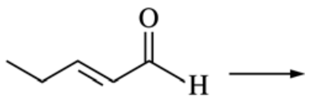
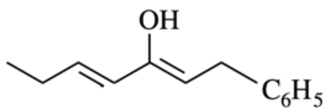
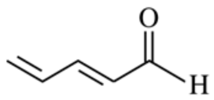
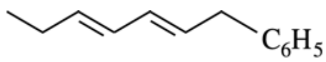
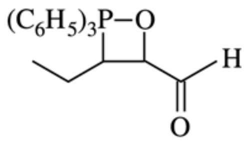
$(C_6H_5)_3P{=}CHCH_2C_6H_5$ + 

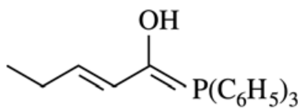
82. Which of the following is the major product of the reaction shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

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$$A \rightarrow \text{Products}$$

83. For the reaction shown above, the experimental rate law is rate $= k[A]^2$. Which of the following is the integrated rate law for this reaction?

(A) $\dfrac{[A]_0}{[A]} = kt$

(B) $\ln\dfrac{[A]_0}{[A]} = kt$

(C) $[A] - [A]_0 = kt$

(D) $[A]^2 - [A]_0^2 = kt$

(E) $\dfrac{1}{[A]} - \dfrac{1}{[A]_0} = kt$

$$NO + NO \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} N_2O_2$$

$$N_2O_2 + O_2 \xrightarrow{k_2} 2\ NO_2$$

84. Consider the mechanism shown above for oxidation of NO by O_2. Based on the steady state approximation, which of the following conditions is true for this mechanism?

(A) $\dfrac{d[NO_2]}{dt} = 2\dfrac{d[N_2O_2]}{dt}$

(B) $\dfrac{d[NO_2]}{dt} = 0$

(C) $\dfrac{d[N_2O_2]}{dt} = 0$

(D) $[N_2O_2] = 0$

(E) $k_2 = k_1 + k_{-1}$

$$A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} B \qquad K_1 = \frac{[B]_{eq}}{[A]_{eq}} = 1$$

$$A \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} C \qquad K_2 = \frac{[C]_{eq}}{[A]_{eq}} = 2$$

$$k_1 = 10\,k_2$$

at $t = 0$: $[B] = [C] = 0$

85. Given the information above, the concentrations of B and C and the control (thermodynamic or kinetic) of the system at short and long times are described by which of the following?

	Short Time	Long Time
(A)	[B] > [C] kinetic	[C] > [B] thermodynamic
(B)	[C] > [B] kinetic	[B] > [C] thermodynamic
(C)	[B] > [C] thermodynamic	[C] > [B] kinetic
(D)	[C] > [B] thermodynamic	[B] > [C] kinetic
(E)	[B] > [C] kinetic	[B] > [C] kinetic

86. In $CrF_2(s)$, the coordination of the six F's around the Cr is a distorted octahedron with four short and two long Cr—F bonds. Which of the following best explains this observation?

(A) F has a −1 anionic charge.
(B) Cr^{2+} has a low cationic charge.
(C) The Jahn-Teller effect
(D) Spin-orbit coupling in Cr^{2+}
(E) The formation of Cr—Cr bonds in $CrF_2(s)$

87. Each of the following molecules can act as a chelating ligand EXCEPT

(A) $H_2NCH_2CH_2NH_2$
(B) $CH_3NHCH_2CH_2NH_2$
(C) $HC(CH_2CH_2NH_2)_3$
(D) $CH_3NHCH_2CH_2CH_3$
(E) $N(CH_2CH_2NH_2)_3$

88. Which of the following is NOT a desirable property of an indicator to be used in a complexometric titration that involves EDTA?

(A) The indicator should be a Lewis base.
(B) The indicator should bind more tightly to the analyte metal than does EDTA.
(C) The complexation reaction between the indicator and the analyte metal should be reversible.
(D) The uncomplexed form of the indicator should be a different color than the indicator-metal complex.
(E) The indicator should be highly soluble in the sample.

89. Which of the following statements about complexes that form between metals, M^{n+}, and EDTA in aqueous solutions is true?

(A) Metal-EDTA complexes have an equilibrium concentration that is independent of pH.
(B) Metal-EDTA complexes are usually highly colored.
(C) Metal-EDTA complexes are often 2:1 in stoichiometry.
(D) Metal-EDTA complexes are less stable than the corresponding metal-ammine complexes.
(E) The presence of other complexing ligands in solution affects the equilibrium concentrations of metal-EDTA complexes.

90. Which of the following compounds exists in stereoisomeric forms?

(A) $[Pt(NH_3)_4]^{2+}$
(B) $[Pt(NH_3)_3Cl]^{+}$
(C) $[Pt(NH_3)_2Cl_2]$
(D) $[Pt(NH_3)Cl_3]^{-}$
(E) $[PtCl_4]^{2-}$

91. All of the following are recognized as pathways that can reduce the CO_2 level in the atmosphere EXCEPT

(A) dissolution in the oceans
(B) photosynthesis
(C) respiration
(D) reduced burning of fossil fuels
(E) rainfall with dissolved CO_2

92. Which of the following is a wavefunction, $\psi(r,\theta,\phi)$, for an s electron?

(A) $N\left(2-\frac{Zr}{a}\right)e^{\frac{-Zr}{2a}}$

(B) $N\,re^{\frac{-Zr}{2a}}\cos\theta$

(C) $N\,re^{\frac{-Zr}{2a}}\sin\theta\cos\phi$

(D) $N\,re^{\frac{-Zr}{2a}}\sin\theta\sin\phi$

(E) $N\,r^2e^{\frac{-Zr}{3a}}\left(3\cos^2\theta-1\right)$

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93. Due to electron-electron interactions, it is not possible to obtain exact solutions to the Schrödinger equation for many-electron atoms. One approach that addresses this difficulty uses

(A) the rigid-rotor approximation
(B) the harmonic oscillator approximation
(C) the principle of corresponding states
(D) effective nuclear charges
(E) the Franck-Condon principle

94. Of the following linear combinations of atomic orbitals centered on two atoms, A and B, which best represents the ground-state molecular orbital for the hydrogen molecule, H_2 ?

(A) $\psi = N(1s_A + 1s_B)$
(B) $\psi = N(1s_A - 1s_B)$
(C) $\psi = N(1s_A + 2p_B)$
(D) $\psi = N(1s_A - 2p_B)$
(E) $\psi = N(2p_A + 2p_B)$

95. Acetic acid is extracted from ether into water. Which of the following actions will NOT increase the fraction of acetic acid removed from ether?

(A) Raising the pH of the water
(B) Increasing the volume of water
(C) Decreasing the volume of ether
(D) Adding benzoic acid to the water
(E) Adding ammonia to the water

96. The ionic strength of an aqueous 0.10 M $Pb(NO_3)_2$ solution is

(A) 0.10 M
(B) 0.25 M
(C) 0.30 M
(D) 0.50 M
(E) 0.60 M

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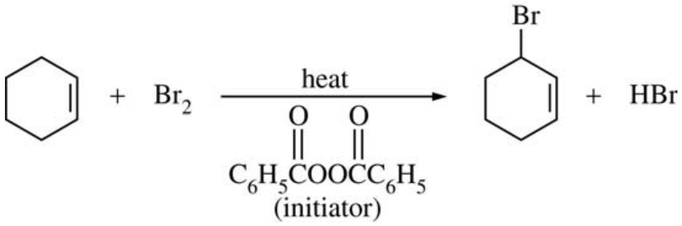
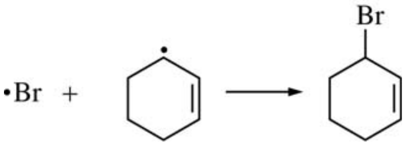
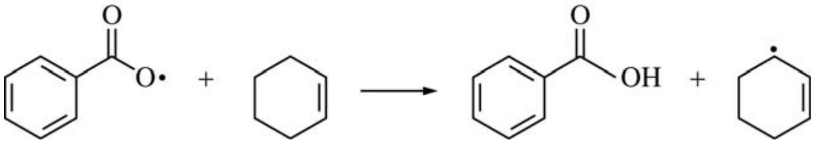


97. Which two of the following are the propagation steps in the allylic bromination of cyclohexene shown above?

I.

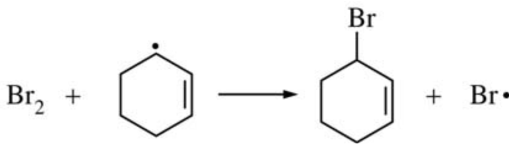


II.

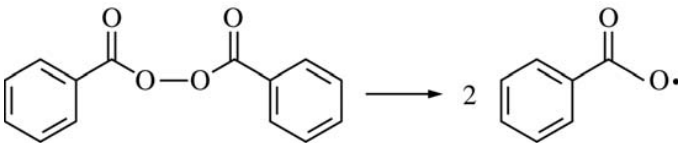


III.

IV.



V.

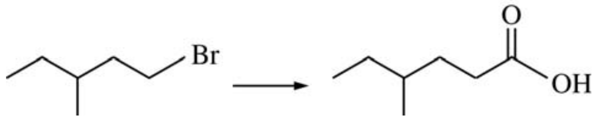


(A) I and II
(B) I and IV
(C) I and V
(D) II and V
(E) III and IV

$$CH_3CH_2CH{=}CH_2 \longrightarrow CH_3CH_2CH_2\overset{OH}{\overset{|}{CH_2}}$$

98. The transformation shown above is carried out by which of the following reagents?

(A) KOH
(B) BH_3/THF then H_2O_2, NaOH
(C) $Hg(O_2CCH_3)_2/H_2O$ then $NaBH_4$
(D) H_2O, H_2SO_4
(E) H_2O, peroxides



99. Which of the following could carry out the conversion shown above?

(A) 1. Mg, ether
2. CO_2
3. H_3O^+

(B) 1. O_3
2. Zn, H_2O

(C) 1. $KMnO_4$, OH^-
2. H_3O^+

(D) 1. NaOH
2. CrO_3, H_2SO_4

(E) 1. Li
2. $H_2C{=}O$
3. H_3O^+

100. Vitamin B_{12}, an essential nutrient for humans, contains which of the following elements?

(A) Cobalt
(B) Chromium
(C) Copper
(D) Zinc
(E) Iron

101. Which of the following is a strong acid in pure liquid HF?

(A) H_2O
(B) SbF_5
(C) CH_3COOH
(D) NH_3
(E) NaF

102. What is the most common natural form in which fluorine is found on Earth?

(A) As a fluoride ion in various minerals
(B) As $XeF_2(s)$
(C) As the weak acid $HF(aq)$
(D) As the free element $F_2(g)$
(E) In various fluorocarbon compounds in the atmosphere

$$E_n = n^2h^2/8mL^2$$

103. For a particle of mass m in a one-dimensional box of length L, the energy of the particle is given by the equation shown above. How much energy is required to promote the particle from the state with quantum number $n = 2$ to the state with quantum number $n = 3$?

(A) $9h^2/8mL^2$
(B) $5h^2/8mL^2$
(C) $4h^2/8mL^2$
(D) $h^2/8mL^2$
(E) 0

104. A large activation energy implies which of the following about a reaction?

(A) It is spontaneous.
(B) It is highly endothermic.
(C) It is at equilibrium.
(D) It is very rapid.
(E) It has a highly temperature-dependent rate constant.

GO ON TO THE NEXT PAGE.

105. Analysis of a bottle of 100 mg vitamin C tablets yields an average vitamin C content of 99.8 mg, with a standard deviation of ±0.3 mg. Assuming Gaussian statistics, which of the following is true?

(A) None of the tablets contains less than 99.5 mg of vitamin C.
(B) 68% of the tablets contain between 99.5 and 100.1 mg of vitamin C.
(C) 97% of the tablets contain between 99.5 and 100.1 mg of vitamin C.
(D) All of the tablets contain less than 100 mg of vitamin C.
(E) The average value is incorrect.

106. In an experiment to test the de Broglie hypothesis, a beam of high-energy electrons with momenta

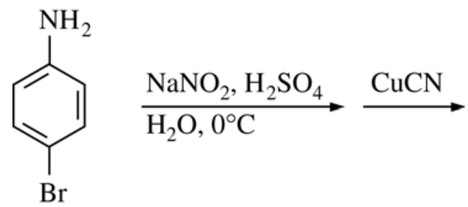
$$p = m_e \upsilon = 6 \times 10^{-24}\ \text{kg}\cdot\text{m/s}$$

would be scattered by a nickel crystal with a pattern similar to that of which of the following?

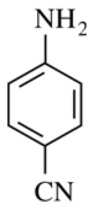
(A) X-rays of wavelength $\lambda = h/p$
(B) Electromagnetic radiation with wavelength $\lambda = p/h$
(C) A beam of protons with velocity υ
(D) Billiard balls undergoing perfectly elastic collisions
(E) Visible light with a mixture of frequencies frequently characterized as “white”

107. Which of the following is true about the quantum yield for photodecomposition of a chromophore?

(A) It depends on the intensity of the light source used for the photolysis.
(B) It depends on the duration of the light source used for the photolysis.
(C) It is the reciprocal of the fluorescence lifetime.
(D) It has a value of either 0 or 1, reflecting the quantum nature of photons.
(E) It is the ratio of the number of chromophores decomposed to the number of photons absorbed.



108. Which of the following is the major organic product of the reaction sequence shown above?

(A)


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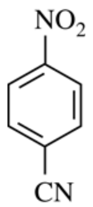

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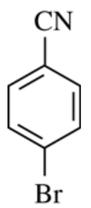

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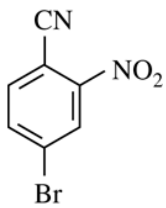
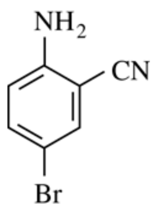
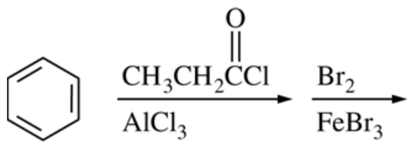
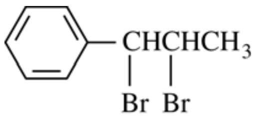
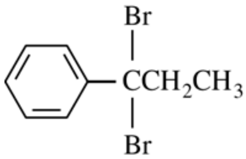


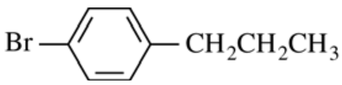
(E)


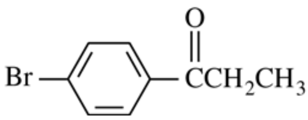


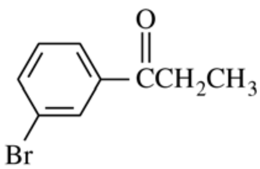
109. Which of the following is the major organic product of the sequence of reactions shown above?

(A) 

(B) 

(C)  and ortho isomer

(D)  and ortho isomer

(E) 

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110. A characteristic common to polymers that can be made to conduct electricity, such as polyacetylene and polypyrrole, is

(A) the presence of stereogenic centers of the same configuration
(B) a monodisperse distribution in molecular weight
(C) a very low glass transition temperature
(D) conjugation throughout the polymer chain
(E) a high degree of cross-linking

111. Which of the following complexes does NOT contain a significant π component in the metal-ligand bonding?

(A) $[Co(NH_3)_6]^{3+}$
(B) $[Fe(CO)_5]$
(C) $[CrO_4]^{2-}$
(D) $[Co(CN)_6]^{3-}$
(E) $[Cr(\eta\text{-}C_6H_6)_2]$

112. In an experiment to determine riboflavin by fluorescence spectrometry, a series of riboflavin standards was analyzed and gave a calibration line with a slope of $1000\ \text{ppm}^{-1}$ and a y-intercept of 25. If a sample gave a fluorescence reading of 750, the riboflavin concentration (in ppm) of the sample is

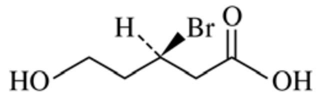
(A) 0.0750
(B) 0.0775
(C) 0.725
(D) 0.775
(E) 7.50

113. The rate constant for a first-order reaction $R \rightarrow P$ is $0.010\ s^{-1}$. The concentration of R decreases to one-half of its initial value after

(A) $\frac{2}{0.010}\ s$
(B) $\frac{\ln 2}{0.010}\ s$
(C) $\frac{1}{2(0.010)}\ s$
(D) $\frac{1}{4(0.010)}\ s$
(E) $5(0.010)\ s$

114. The activated-complex theory (or transition state theory) assumes that an equilibrium exists between the

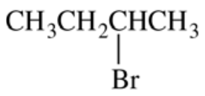
(A) activated complex and reactants only
(B) activated complex and products only
(C) products and reactants only
(D) reactants, activated complex, and products
(E) system (reaction) and surroundings

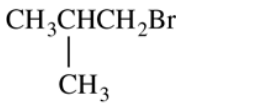


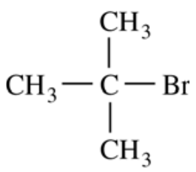
115. Oxidation of (R)-3-bromo-5-hydroxypentanoic acid, shown above, yields the corresponding 3-bromopentanedicarboxylic acid product that is

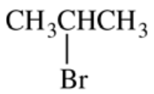
(A) a mixture of two diastereomers in unequal amounts
(B) a racemic mixture
(C) a single pure enantiomer
(D) a meso compound
(E) an achiral compound

116. Of the following molecules, which most readily undergoes a unimolecular elimination (E1) reaction?

(A) 

(B) 

(C) 

(D) 

(E) $CH_3CH_2CH_2CH_2Br$

117. Compounds have been prepared from which of the following noble gas elements?

(A) He only
(B) He and Ne only
(C) Ne and Ar only
(D) He, Ne, and Ar
(E) Kr, Xe, and Rn

118. AgCl is insoluble in water at room temperature. The dissolution of AgCl(*s*) into aqueous ammonia can best be explained as the

(A) coprecipitation of $NH_4Cl(s)$
(B) formation of $AgNO_3$
(C) oxidation of Ag^+ in aqueous base
(D) reduction of Ag^+ by NH_3
(E) formation of the complex cation $Ag(NH_3)_2^+$

$$\frac{d[\mathrm{HBr}]}{dt} = k[\mathrm{H_2}][\mathrm{Br_2}]^{\frac{1}{2}}$$

119. The rate law shown above is for the reaction $H_2 + Br_2 \rightarrow 2\,HBr$ at the early stages of the reaction, when [HBr] is low and holds over a wide range of concentrations of H_2 and Br_2. An explanation that is consistent with the half-integer order in Br_2 is given by which of the following?

(A) The mechanism is an elementary reaction involving one Br_2 and two H_2 molecules.
(B) The overall reaction is not accomplished by a single elementary step.
(C) The rate-limiting step involves one Br_2 and two H_2 molecules.
(D) The rate-limiting step involves one H_2 and two Br_2 molecules.
(E) Quantum mechanical tunneling affects the rate.

120. In a mixture of He and Ar atoms in thermal equilibrium, what is the average speed of the He atoms, υ_{He}, compared with the average speed of the Ar atoms, υ_{Ar}? (m_{He} is the mass of He atoms, and m_{Ar} is the mass of Ar atoms.)

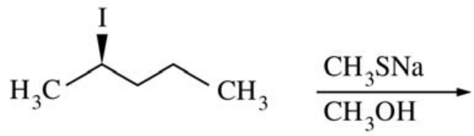
(A) $\upsilon_{\text{He}} = \upsilon_{\text{Ar}}$

(B) $\dfrac{\upsilon_{\text{He}}}{\upsilon_{\text{Ar}}} = \dfrac{m_{\text{He}}}{m_{\text{Ar}}}$

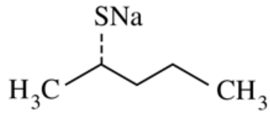
(C) $\dfrac{\upsilon_{\text{He}}}{\upsilon_{\text{Ar}}} = \dfrac{m_{\text{Ar}}}{m_{\text{He}}}$

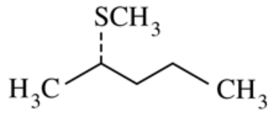
(D) $\dfrac{\upsilon_{\text{He}}}{\upsilon_{\text{Ar}}} = \sqrt{\dfrac{m_{\text{He}}}{m_{\text{Ar}}}}$

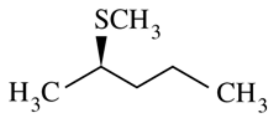
(E) $\dfrac{\upsilon_{\text{He}}}{\upsilon_{\text{Ar}}} = \sqrt{\dfrac{m_{\text{Ar}}}{m_{\text{He}}}}$



121. Which of the following is the major nucleophilic substitution product of the reaction shown above?

(A)


(B)


(C)


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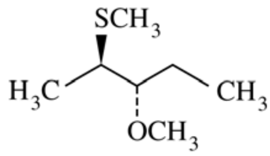

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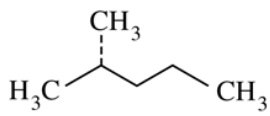

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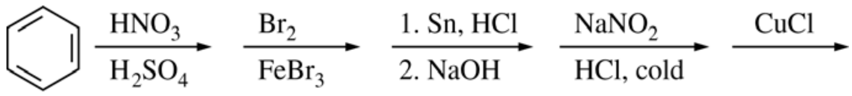
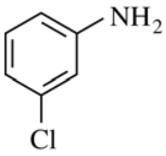
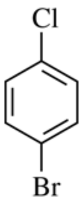
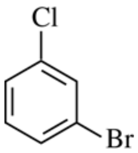
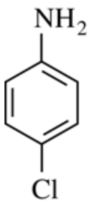


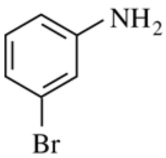
122. What is the major organic product from the sequence of reactions shown above?

(A)


(B)


(C)


(D)


(E)


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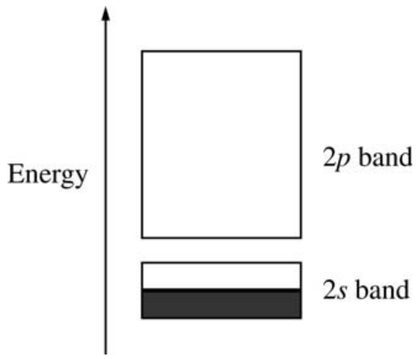


123. A simple electronic band structure for lithium metal is shown above. Based on this band structure, which of the following is correct?

(A) Electrons occupy one of two distinct energy states in the $2s$ band.
(B) If the number of lithium atoms in a piece of lithium metal is represented by N, then the number of $2s$ orbitals that make up the $2s$ band is $2N$.
(C) The electrons in the $2s$ band are each localized on a particular lithium atom.
(D) Electrons must be promoted to the $2p$ band in order to conduct.
(E) The partial filling of the $2s$ band is responsible for the metallic character of lithium.

$H_3C—O—C(CH_3)_3$

124. Methyl *t*-butyl ether (MTBE), shown above, is a controversial gasoline additive. Of the following analytical techniques, which would be the best method to measure quantitatively trace amounts of MTBE in contaminated groundwater?

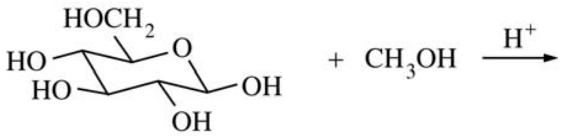
(A) Capillary electrophoresis
(B) Gas chromatography
(C) Atomic absorption spectroscopy
(D) Fluorescence spectroscopy
(E) EPR spectroscopy

125. For the species H_2, HD, HT, and D_2, all of the bond strengths (and force constants) are the same. Which of the following will have the lowest fundamental vibration frequency?
(D = deuterium; T = tritium)

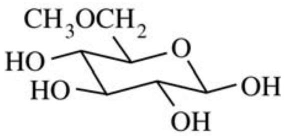
(A) H_2
(B) HD
(C) HT
(D) D_2
(E) All will have the same fundamental vibration frequency.

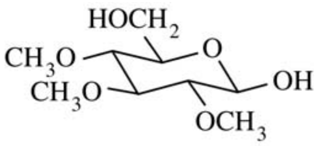
126. Which of the following is NOT true about Raman scattering?

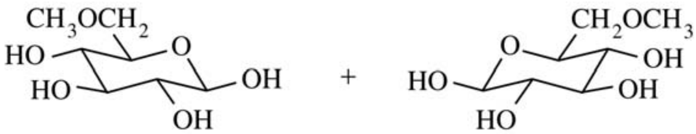
(A) Raman scattering requires a change in dipole moment.
(B) Raman frequency shifts are independent of the frequency of excitation.
(C) Raman scattering results in equal shifts in frequency above and below the incident frequency.
(D) Some Raman-active transitions are not infrared active.
(E) Raman scattering requires a change in polarizability.

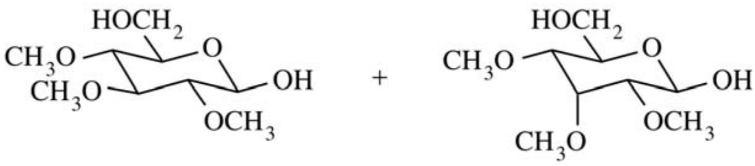


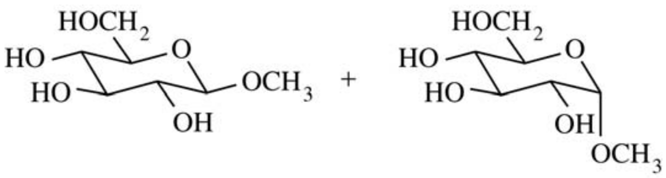
127. Which of the following is formed when a solution of β-D-glucopyranose is allowed to stand in methanol that contains a small amount of an acid catalyst, as indicated in the equation shown above?

(A) 

(B) 

(C) 

(D) 

(E) 

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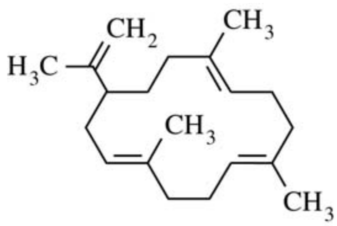


128. The species shown above is

(A) a nucleotide
(B) a peptide
(C) a diterpene
(D) a disaccharide
(E) an alkaloid

129. Which of the following is NOT a known, relatively stable compound of uranium?

(A) UF_6
(B) UO_2
(C) UO_3
(D) $U(CH_3)_2$
(E) $U(C_8H_8)_2$

pK_{a1}	2.15
pK_{a2}	7.20
pK_{a3}	12.15

130. The pK_{a1}, pK_{a2}, and pK_{a3} values for H_3PO_4 are given above. When 50.0 mL of 0.10 M Na_2HPO_4 are mixed with 50.0 mL of 0.10 M Na_3PO_4, the pH of the resulting solution will be closest to

(A) 2.15
(B) 4.68
(C) 7.20
(D) 9.68
(E) 12.15

If you finish before time is called, you may check your work on this test.

NO TEST MATERIAL ON THIS PAGE

NO TEST MATERIAL ON THIS PAGE

I

NOTE: To ensure prompt processing of test results, it is important that you fill in the blanks exactly as directed.

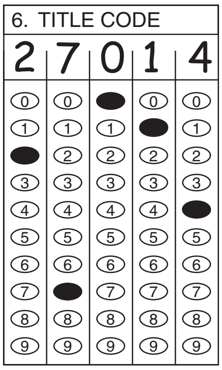
SUBJECT TEST

A. Print and sign your full name in this box:

PRINT: ____
(LAST) (FIRST) (MIDDLE)

SIGN: ____

Copy this code in box 6 on your answer sheet. Then fill in the corresponding ovals exactly as shown.



Copy the Test Name and Form Code in box 7 on your answer sheet.

TEST NAME Chemistry

FORM CODE GR0627

GRADUATE RECORD EXAMINATIONS SUBJECT TEST

B. The Subject Tests are intended to measure your achievement in a specialized field of study. Most of the questions are concerned with subject matter that is probably familiar to you, but some of the questions may refer to areas that you have not studied.

Your score will be determined by subtracting one-fourth the number of incorrect answers from the number of correct answers. Questions for which you mark no answer or more than one answer are not counted in scoring. If you have some knowledge of a question and are able to rule out one or more of the answer choices as incorrect, your chances of selecting the correct answer are improved, and answering such questions will likely improve your score. It is unlikely that pure guessing will raise your score; it may lower your score.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult for you. Go on to the other questions and come back to the difficult ones later if you can.

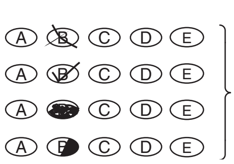
YOU MUST INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination book, but you may write in the book as much as you wish to work out your answers. After you have decided on your response to a question, fill in the corresponding oval on the answer sheet. BE SURE THAT EACH MARK IS DARK AND COMPLETELY FILLS THE OVAL. Mark only one answer to each question. No credit will be given for multiple answers. Erase all stray marks. If you change an answer, be sure that all previous marks are erased completely. Incomplete erasures may be read as intended answers. Do not be concerned that the answer sheet provides spaces for more answers than there are questions in the test.

Example:

What city is the capital of France?

(A) Rome
(B) Paris
(C) London
(D) Cairo
(E) Oslo

Sample Answer



CORRECT ANSWER PROPERLY MARKED

IMPROPER MARKS

DO NOT OPEN YOUR TEST BOOK UNTIL YOU ARE TOLD TO DO SO.

Educational Testing Service
Princeton, New Jersey 08541

Scoring Your Subject Test

The Chemistry Test scores are reported on a 200 to 990 score scale in ten-point increments. The actual range of scores is smaller, and it varies from edition to edition because different editions are not of precisely the same difficulty. However, this variation in score range is usually small and should be taken into account mainly when comparing two very high scores. In general, differences between scores at the 99th percentile should be ignored. **The score conversion table on page 55 shows the score range for this edition of the test only.**

The worksheet on page 54 lists the correct answers to the questions. Columns are provided for you to mark whether you chose the correct (C) answer or an incorrect (I) answer to each question. Draw a line across any question you omitted, because it is not counted in the scoring. At the bottom of the page, enter the total number correct and the total number incorrect. Divide the total incorrect by 4 and subtract the resulting number from the total correct. Then round the result to the nearest whole number. This will give you your raw total score. Use the total score conversion table to find the scaled total score that corresponds to your raw total score.

Example: Suppose you chose the correct answers to 80 questions and incorrect answers to 46. Dividing 46 by 4 yields 11.5. Subtracting 11.5 from 80 equals 68.5, which is rounded to 69. The raw score of 69 corresponds to a scaled score of 690.

Worksheet for the Chemistry Test, Form GR0627
Answer Key and Percentages* of Examinees Answering Each Question Correctly

QUESTION Number	QUESTION Answer	P+	RESPONSE C	RESPONSE I
1	A	83		
2	C	83		
3	C	64		
4	D	63		
5	C	90		
6	B	91		
7	B	47		
8	D	72		
9	C	48		
10	B	92		
11	C	85		
12	C	59		
13	D	87		
14	A	70		
15	E	50		
16	C	42		
17	A	71		
18	D	86		
19	E	78		
20	E	50		
21	E	82		
22	B	60		
23	E	45		
24	C	68		
25	B	48		
26	E	71		
27	C	60		
28	D	23		
29	A	67		
30	B	85		
31	C	60		
32	D	86		
33	A	62		
34	A	50		
35	A	73		
36	E	66		
37	E	61		
38	E	53		
39	D	55		
40	D	60		
41	A	82		
42	A	52		
43	B	83		
44	D	40		
45	C	62		

QUESTION Number	QUESTION Answer	P+	RESPONSE C	RESPONSE I
46	C	89		
47	D	69		
48	B	57		
49	E	50		
50	A	15		
51	A	44		
52	E	69		
53	A	72		
54	D	27		
55	B	69		
56	B	51		
57	C	64		
58	E	39		
59	E	50		
60	A	76		
61	A	34		
62	C	58		
63	A	32		
64	D	48		
65	E	53		
66	A	45		
67	A	74		
68	D	51		
69	D	59		
70	D	79		
71	B	65		
72	B	76		
73	D	37		
74	B	97		
75	A	75		
76	E	62		
77	A	77		
78	B	80		
79	C	62		
80	C	38		
81	A	78		
82	C	56		
83	E	62		
84	C	60		
85	A	63		
86	C	72		
87	D	68		
88	B	53		
89	E	54		
90	C	71		

QUESTION Number	QUESTION Answer	P+	RESPONSE C	RESPONSE I
91	C	89		
92	A	32		
93	D	23		
94	A	75		
95	D	62		
96	C	68		
97	E	67		
98	B	66		
99	A	73		
100	A	30		
101	B	27		
102	A	72		
103	B	87		
104	E	65		
105	B	58		
106	A	47		
107	E	51		
108	C	27		
109	E	48		
110	D	77		
111	A	51		
112	C	76		
113	B	69		
114	A	29		
115	E	36		
116	C	78		
117	E	78		
118	E	55		
119	B	51		
120	E	63		
121	B	79		
122	C	31		
123	E	36		
124	B	66		
125	D	47		
126	A	40		
127	E	43		
128	C	66		
129	D	27		
130	E	42		

Total Correct (**C**) ______________________________

Total Incorrect (**I**) ______________________________

Total Score:

C – **I**/4 = ___________

Scaled Score (SS) = ___________

* The P+ column indicates the percent of CHEMISTRY Test examinees who answered each question correctly; it is based on a sample of November 2006 examinees selected to represent all CHEMISTRY Test examinees tested between July 1, 2005, and June 30, 2008.