FORM GR9527

27

THE GRADUATE RECORD
EXAMINATIONS®

GRE®

CHEMISTRY TEST

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PERIODIC TABLE OF THE ELEMENTS

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 16.00	9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
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 54.938	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 (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 § (269)	111 § (272)	112 § (277)						

§Not yet named

*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 237.05	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 (260)

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

TABLE OF INFORMATION

Electron rest mass	$m_e = 9.11 \times 10^{-31}$ kilogram
Proton rest mass	$m_p = 1.673 \times 10^{-27}$ kilogram
Neutron rest mass	$m_n = 1.675 \times 10^{-27}$ kilogram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb
Bohr radius	$a_0 = 5.29 \times 10^{-11}$ meter
Avogadro number	$N_A = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.314$ joules/(mole·K) $= 0.0821$ L·atm/(mole·K)
Boltzmann constant	$k = 1.38 \times 10^{-23}$ joule/K
Planck constant	$h = 6.63 \times 10^{-34}$ joule·second
Speed of light	$c = 3.00 \times 10^{8}$ meters/second
1 atmosphere pressure	$1 \text{ atm} = 1.0 \times 10^{5}$ newton/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
Faraday constant	$\mathcal{F} = 9.65 \times 10^{4}$ coulombs/mole
1 atomic mass unit (amu)	$1 \text{ amu} = 1.66 \times 10^{-27}$ kilogram
1 eV	$1 \text{ eV} = 1.602 \times 10^{-19}$ joule
Volume of 1 mole of ideal gas at 0°C, 1 atmosphere	$= 22.4$ liters

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CHEMISTRY TEST

Time—170 minutes

144 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.

Note: Solutions are aqueous unless otherwise specified.

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

T = temperature
P = pressure
V = volume
S = entropy
H = enthalpy
U = internal energy
R = molar gas constant
n = number of moles

1. Which of the following substances is NOT a good oxidizing agent?

   (A) O_2
   (B) H_2O_2
   (C) Na
   (D) Cl_2
   (E) MnO_4^-

2. The structure of the IF_5 molecule in solution is square pyramidal. Its low-temperature ^{19}F nuclear magnetic resonance (NMR) spectrum should exhibit which of the following patterns? (^{19}F is 100% abundant with a nuclear spin of 1/2; ignore any effects due to magnetic coupling to iodine nuclei.)

   (A) One singlet
   (B) One sextet
   (C) One triplet with an integrated intensity of three and one quartet with an integrated intensity of two
   (D) One quartet with an integrated intensity of three and one triplet with an integrated intensity of two
   (E) One doublet with an integrated intensity of four and one quintet with an integrated intensity of one

3. In which of the following reactions is the equilibrium farthest to the left?

   (A) $P_4O_{10} + x\ H_2O \rightleftharpoons 4\ H_3PO_4(aq)$

   (B) $AlCl_3 + x\ H_2O \rightleftharpoons [Al(H_2O)_6]^{3+} + 3\ Cl^-(aq)$

   (C) $Li_2O + x\ H_2O \rightleftharpoons 2\ Li^+(aq) + 2\ OH^-(aq)$

   (D) $H_2S + H_2O \rightleftharpoons H_3O^+ + HS^-(aq)$

   (E) $CaC_2 + x\ H_2O \rightleftharpoons Ca^{2+}(aq) + 2\ OH^-(aq) + C_2H_2(g)$

GO ON TO THE NEXT PAGE.

4. How many unpaired electrons are there in a ground-state titanium atom?

(A) Zero
(B) One
(C) Two
(D) Three
(E) Four

5. For phosphoric acid, $K_{a_1} = 7.6 \times 10^{-3}$, $K_{a_2} = 6.2 \times 10^{-8}$, $K_{a_3} = 4.8 \times 10^{-13}$. In order of decreasing concentrations, which of the following is correct about the concentration of the listed species present in a solution of H_3PO_4 at pH = 1.0?

I. $[H_3PO_4]$
II. $[H_2PO_4^-]$
III. $[HPO_4^{2-}]$
IV. $[PO_4^{3-}]$

(A) I > II > III > IV
(B) II > III > IV > I
(C) III > II > IV > I
(D) IV > II > III > I
(E) IV > III > II > I

6. Which of the following CANNOT be determined quantitatively by direct titration with a standard potassium permanganate solution under appropriate conditions?

(A) Ca(II)
(B) Fe(II)
(C) Sn(II)
(D) As(III)
(E) Sb(III)

7. The separation of ions in a mass spectrometer is fully determined by the

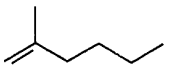
(A) charge of the ions
(B) mass of the ions
(C) size of the ions
(D) mass-to-charge ratio of the ions
(E) number of ions

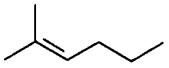
8. $$Fe^{2+} \rightleftharpoons Fe^{3+} + e^-$$
$$MnO_4^- + 8\ H^+ + 5\ e^- \rightleftharpoons Mn^{2+} + 4\ H_2O$$

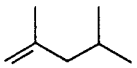
The half reactions involved in the oxidation of Fe^{2+} to Fe^{3+} with MnO_4^- are given above. The ratio of the number of moles of Fe^{2+} to the number of moles of MnO_4^- in the overall reaction is given by which of the following?

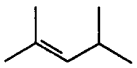
	Moles of Fe^{2+}	Moles of MnO_4^-
(A)	1	1
(B)	1	2
(C)	1	5
(D)	2	5
(E)	5	1

9. A certain alkene (C_7H_{14}) exhibits seven signals in its proton-coupled ^{13}C nuclear magnetic resonance spectrum. Of the seven signals, two are quartets, one is a singlet, and four are triplets. Which of the following structures is consistent with these data?

(A) 

(B) 

(C) 

(D) 

(E) 

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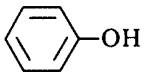
10. I. $CH_3-CH_2-CO_2H$

II. $CH_3-CH_2-CH_2-OH$

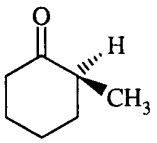
III. 

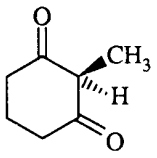
IV. $CH_3-C\equiv C-H$

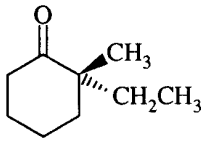
Which of the following indicates the order of decreasing acidity of the four molecules above?

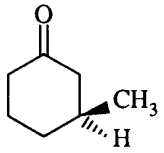
(A) I > III > II > IV
(B) II > I > IV > III
(C) II > III > I > IV
(D) III > II > IV > I
(E) IV > II > III > I

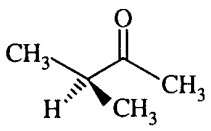
11. Which of the following compounds undergoes conversion to a racemic mixture of enantiomers upon treatment with base?

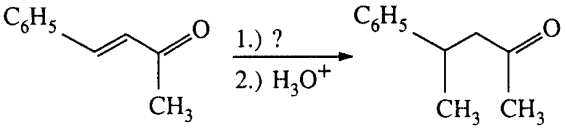
(A) 

(B) 

(C) 

(D) 

(E) 

12. 

Which of the following reagents would be best for effecting the transformation shown above?

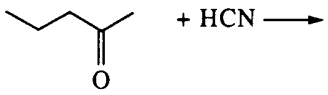
(A) CH_3MgBr

(B) CH_3MgCl

(C) CH_3I

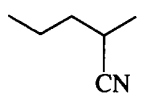
(D) CH_3Li

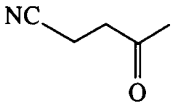
(E) $(CH_3)_2CuLi$

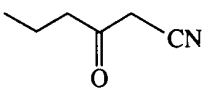
13. 

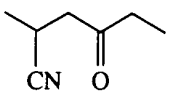
The reaction above should be expected to produce which of the following?

(A) 

(B) 

(C) 

(D) 

(E) 

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14. One liter-atmosphere is approximately how many joules?

(A) 0.01 J
(B) 0.1 J
(C) 1.0 J
(D) 10 J
(E) 100 J

15. Which of the following molecules has the greatest bond energy?

(A) N_2
(B) O_2
(C) F_2
(D) Cl_2
(E) Br_2

16. When 3.00 grams of a nonelectrolyte is dissolved in 100. grams of water, the freezing point of the resulting solution is $-0.465°C$. What is the molecular weight of the nonelectrolyte?

$\left[K_f \text{ for water is } 1.86 \ \frac{C° \cdot kg}{mole} . \right]$

(A) 25.9 grams/mole
(B) 34.7 grams/mole
(C) 120. grams/mole
(D) 168 grams/mole
(E) 259 grams/mole

17. The ionization energy of H is 13.6 electron volts (eV). The first and second ionization energies of He must be approximately

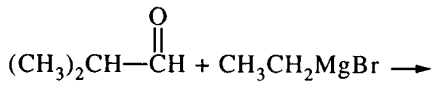
(A) 5 eV and 14 eV
(B) 5 eV and 54 eV
(C) 14 eV and 24 eV
(D) 14 eV and 34 eV
(E) 24 eV and 54 eV

18. The linear momentum operator in quantum mechanics is $\hat{P}_x = -i\hbar \frac{\partial}{\partial x}$, where $i^2 = -1$ and $\hbar$ is the Planck constant divided by 2π, that is, $h/2\pi$. Which of the following functions is an eigenfunction of $\hat{P}_x$ having a real eigenvalue? (The quantity k is a constant.)

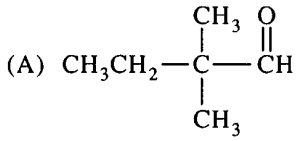
(A) e^{-kx}
(B) e^{kx}
(C) e^{ikx}
(D) e^{-kx^2}
(E) xe^{ikx}

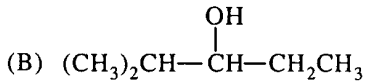
19. The sum of the number of rings and the number of double bonds in a compound having the molecular formula $C_6H_{10}O$ is

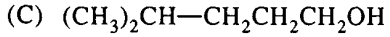
(A) 0
(B) 1
(C) 2
(D) 3
(E) 4

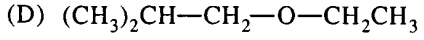
20. 

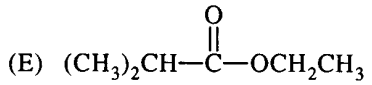
After treatment of the reaction mixture above with aqueous acid, what is the product of the reaction?

(A) 

(B) 

(C) 

(D) 

(E) 

21. Which of the following types of compounds does NOT contain a carbonyl group?

(A) Primary amine
(B) Primary amide
(C) Acid chloride
(D) Ethyl ester
(E) Carboxylic acid

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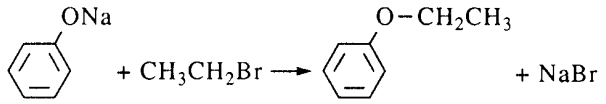
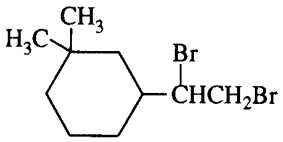
22. 

The reaction above is an example of which of the following?

(A) Elimination
(B) Nucleophilic substitution
(C) Electrophilic addition
(D) Electrophilic aromatic substitution
(E) Aldol condensation

23. 

How many stereoisomers are possible for the compound shown above?

(A) Two
(B) Three
(C) Four
(D) Five
(E) Six

24. In a simple extraction of a monomeric organic compound from water with an immiscible organic solvent, the relative distribution ratio, D_r, is defined as the concentration of solute in the organic phase relative to that in the water. The D_r value is 50. How many milligrams of solute will remain in 200. milliliters of water if after extraction there are 10.0 milligrams of solute in the 100.-milliliter volume of organic phase?

(A) 0.05 mg
(B) 0.10 mg
(C) 0.20 mg
(D) 0.40 mg
(E) 0.50 mg

25. A weak acid, HA, ($K_a = 1.0 \times 10^{-4}$) is titrated with NaOH. The concentration of NaA at the equivalence point is 0.010 molar. The pH at the equivalence point is

(A) 3.0
(B) 6.0
(C) 7.0
(D) 8.0
(E) 11.0

26. A 2.0-gram sample containing calcium is treated appropriately to precipitate 3.0 grams of $Ca_3(PO_4)_2$ (molecular mass = 310). The mass percent of calcium in the original sample is closest to

(A) 19%
(B) 26%
(C) 39%
(D) 58%
(E) 67%

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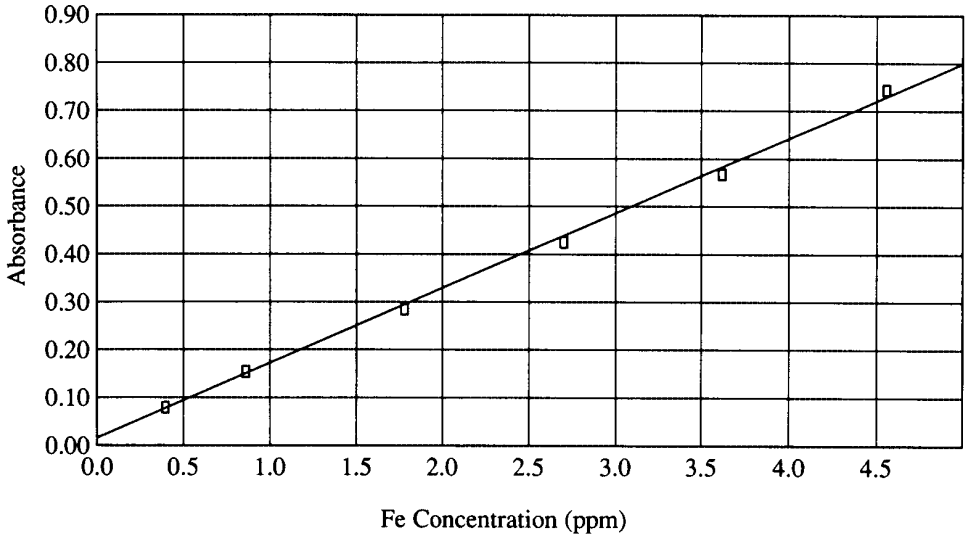
27.



A working curve for the analysis of standard solutions of iron using atomic absorption spectrophotometry is shown above. The curve is most likely used to determine the

(A) iron concentration in the standards
(B) iron concentration in unknown solutions
(C) absorbance in each standard
(D) the wavelength response of the detector
(E) intensity of the light source

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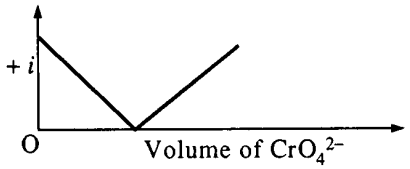
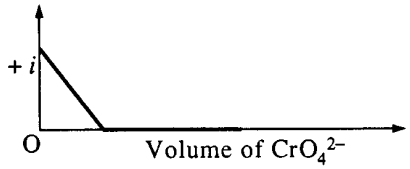
28. $Pb^{2+}(aq) + CrO_4^{2-}(aq) \longrightarrow PbCrO_4(s)$

The amperometric titration of Pb^{2+} with CrO_4^{2-} is carried out at an applied potential where both ions are reducible. The reaction is shown above. The titration curve would resemble most closely which of the following?

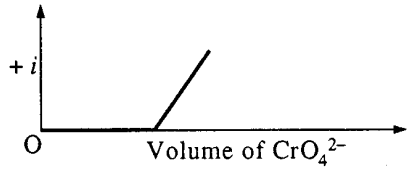
(A)



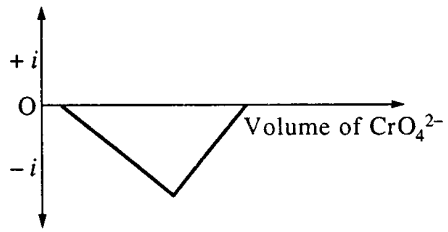
(B)



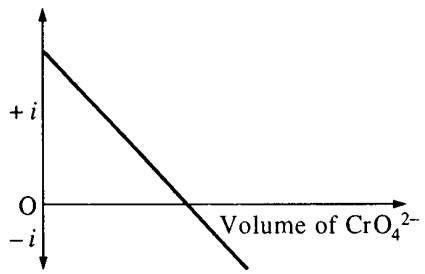
(C)



(D)



(E)



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29. $\frac{1}{2} H_2(g) + \frac{1}{2} Br_2(g) \longrightarrow HBr(g)$

Molecule	Bond Energy (kJ/mole)
H_2	436
Br_2	193
HBr	366

For the reaction above, what is the enthalpy of reaction, ΔH, per mole of HBr formed?

(A) + 103 kJ/mole
(B) + 51.5 kJ/mole
(C) − 51.5 kJ/mole
(D) − 103 kJ/mole
(E) The value cannot be determined from the data given.

30. Assume benzene and toluene form an ideal solution. At a certain temperature, the vapor pressure of pure benzene is 200 torr and that of pure toluene is 70. torr. The mole fraction of benzene in the solution is 0.40. What is the mole fraction of benzene in the vapor in equilibrium with the solution?

(A) 0.19
(B) 0.33
(C) 0.40
(D) 0.66
(E) 0.81

31. The integrated rate law for a second-order reaction is $\frac{1}{[A]} = \frac{1}{[A]_0} + kt$ where A_0 is the initial concentration of A. The expression for the half-life is

(A) $0.693/k$
(B) $k/06.93$
(C) k/A_0
(D) $1/k(A_0)$
(E) $0.693/(kA_0)$

32. $O_3(g) \longrightarrow \frac{3}{2} O_2(g)$

For the reaction above, $\Delta G° = -163$ kilojoules at 298 K. The equilibrium constant K_p for the reaction as written is

(A) 2.7×10^{-29}
(B) 8.8×10^{-20}
(C) 0.94
(D) 1.1
(E) 3.7×10^{28}

33. When concentration is expressed in moles/liter (M), a third-order rate constant has units of

(A) $M \cdot s^{-1}$
(B) $M^3 \cdot s^{-1}$
(C) $M^{-1} \cdot s^{-1}$
(D) $M^{-2} \cdot s^{-1}$
(E) $M^{-3} \cdot s^{-1}$

34. The crystals of Na_2O exhibit an antifluorite structure with a coordination number of 4 for the cation. What must be the coordination number of the anion?

(A) 2 (B) 4 (C) 6 (D) 7 (E) 8

35. Which of the following statements concerning hemoglobin is NOT correct?

(A) Oxygen binds to the porphyrin ligands of the heme groups.
(B) Carbon monoxide is toxic because it has a higher affinity for hemoglobin than oxygen does.
(C) The four heme subunits of hemoglobin exhibit cooperativity in their binding of oxygen.
(D) The binding of oxygen by hemoglobin is pH sensitive.
(E) Hemoglobin binds O_2 reversibly.

36. In which of the following species are the atom-to-atom bonds characteristically more ionic than covalent?

(A) Cl_2 (g)
(B) LiF (s)
(C) CO (g)
(D) H_2 (g)
(E) OH^- (aq)

37. Which of the following species is diamagnetic in its ground state?

(A) O_2^{2-}
(B) O_2^-
(C) O_2
(D) O_2^+
(E) NO

GO ON TO THE NEXT PAGE.

38. Which of the following compounds is the strongest base in water?

(A) B_2O_3
(B) K_2O
(C) Cl_2O
(D) CO_2
(E) P_4O_{10}

39. For a gas the thermal expansion coefficient α is defined by the expression $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$.

For a substance obeying the equation of state $PV = nRT$, which of the following expressions represents α?

(A) $1/T$
(B) nR/T
(C) PV/T
(D) PV/nR
(E) RT/P

40. $$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

Which of the following expressions correctly represents the rate of formation of B, $\frac{d[B]}{dt}$, for the mechanism above?

(A) $k_1[B] + k_2[C]$

(B) $k_1[A] + k_2[C]$

(C) $k_1[A] - k_2[B]$

(D) $k_1[A] - k_2[C]$

(E) $k_1[B] - k_2[C]$

41. The number of unpaired electrons in a molecule in a doublet state is

(A) 0
(B) 1
(C) 2
(D) 3
(E) 4

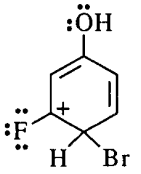
42. The process in which a molecule in an excited singlet state converts to the lowest-lying triplet state is known as

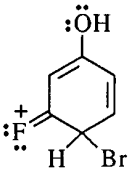
(A) internal conversion
(B) intersystem crossing
(C) a Franck-Condon transition
(D) fluorescence
(E) phosphorescence

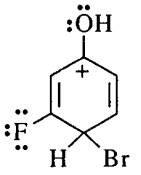
43. When the pressure of a gas is reduced, how do the following properties change?

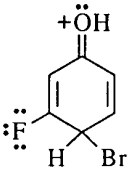
	Collision Rate	Mean Free Path
(A)	Increases	Increases
(B)	Increases	Decreases
(C)	Decreases	Decreases
(D)	Decreases	Increases
(E)	No change	Increases

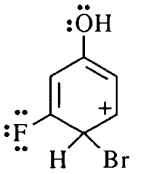
44. Which of the following is the most stable resonance structure for the carbocation intermediate formed in the bromination of *m*-fluorophenol? Hint: Assume that structures that obey the octet rule are more stable. (Unshared electron pairs of Br are not relevant to this problem and have been omitted for clarity.)

(A) 

(B) 

(C) 

(D) 

(E) 

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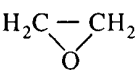
45. Which of the following offers the best combination of reactants to give the highest yield of *tert*-butyl methyl ether, $(CH_3)_3COCH_3$?

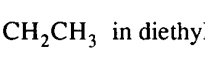
(A) $(CH_3)_2C{=}CH_2 + NaOCH_3$
(B) $(CH_3)_2CHCH_2I + NaOCH_3$
(C) $(CH_3)_3CBr + KOCH_3$
(D) $(CH_3)_3CONa + CH_3OH$
(E) $(CH_3)_3COK + CH_3I$

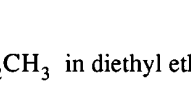
46. Which of the following reaction sequences yields 1-pentanol, $CH_3CH_2CH_2CH_2CH_2OH$, as the major product?

(A) $CH_3CH_2CH_2MgBr$ +  in diethyl ether; followed by H_3O^+

(B) $CH_3CH_2CH_2MgBr$ +  in diethyl ether; followed by H_3O^+

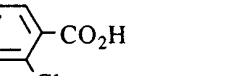
(C) $CH_3CH_2CH_2CH{=}CH_2 + H_2SO_4$; followed by H_2O (heat)

(D) CH_3Li +  in diethyl ether; followed by H_3O^+

(E) CH_3Li +  in diethyl ether; followed by H_3O^+

47. The reaction of benzoic acid with thionyl chloride ($SOCl_2$) yields which of the following?

(A) only

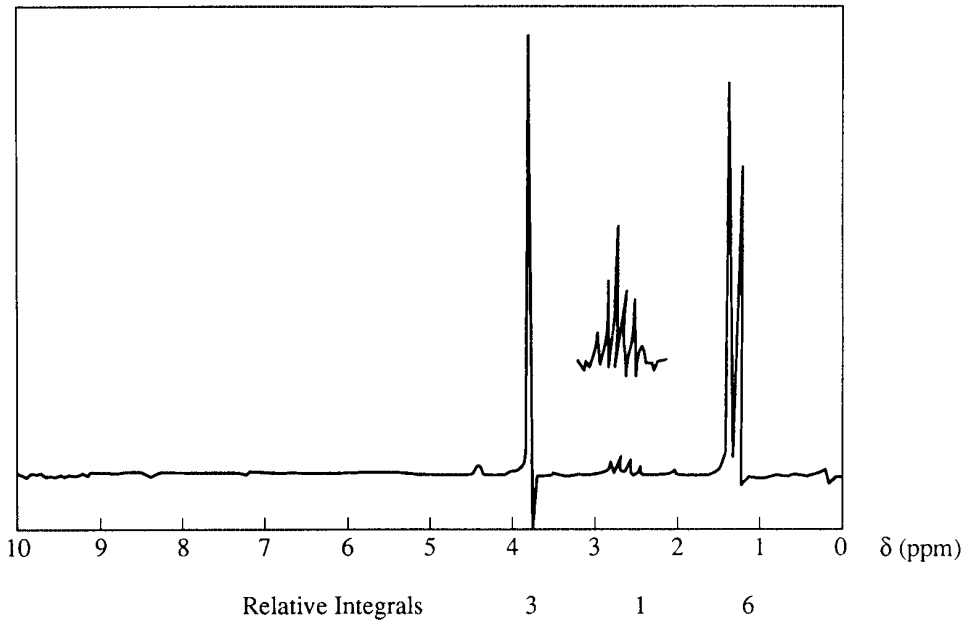
(B)  and

(C)

(D)

(E)

48.



The 60-megahertz proton nuclear magnetic resonance spectrum above is consistent with which of the following structures?

(A) $(CH_3)_2CH-\overset{\overset{O}{\|}}{C}-OCH_3$

(B) $CH_3-\overset{\overset{O}{\|}}{C}-OCH(CH_3)_2$

(C) $CH_3CH_2CH_2CH_2-\overset{\overset{O}{\|}}{C}-OH$

(D) $CH_3-O-CH_2CH_2CH_2-\overset{\overset{O}{\|}}{C}-H$

(E) CH_3-O, HO, $C=C$, CH_3, CH_3

GO ON TO THE NEXT PAGE.

49. Which of the following does NOT exhibit a layer structure in the solid state?

(A) KC_8
(B) $CaCl_2$
(C) Graphite
(D) MoS_2
(E) $Mg_3(OH)_2Si_4O_{10}$(talc)

50. A student's attempt to prepare chloropentamminecobalt(III) chloride, $[Co(NH_3)_5Cl]Cl_2$, was pronounced successful on the basis of appropriate molar conductance measurements. The measurements must have shown the

(A) product to be molecular
(B) presence of two moles of ions per formula weight of product
(C) presence of three moles of ions per formula weight of product
(D) presence of four moles of ions per formula weight of product
(E) presence of nine moles of ions per formula weight of product

51. Liquid ammonia exhibits which of the following types of intermolecular forces?

I. Dipole-dipole forces
II. Hydrogen bonding
III. London (dispersion) forces

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

52. When placed in water, which of the following gives an acidic solution?

(A) NaCl
(B) BaO
(C) SF_6
(D) Na_2O_2
(E) SO_3

53. Which of the following reactions produces a colored solution?

(A) $Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow$
(B) $Ni(s) + AgNO_3(aq) \longrightarrow$
(C) $P_4O_{10}(s) + H_2O \longrightarrow$
(D) $K_2O_2(s) + H_2O \longrightarrow$
(E) $Zn(s) + H_3O^+(aq) \longrightarrow$

54. The retention time of a solute on a gas chromatography column can be decreased by which of the following operations?

I. Increasing the column temperature
II. Lengthening the column
III. Changing the stationary phase to one in which the solute has a larger partition ratio

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

55.

Volume of Titrant (mL)	Potential (mV)	Potential Change per 0.1 mL Volume Change
24.70	210	
		12
24.80	222	
		18
24.90	240	
		120
25.00	360	
		240
25.10	600	
		16
25.20	616	
		9
25.30	625	

The table above contains potential readings near the equivalence point of a potentiometric titration. The volume of titrant needed to reach the equivalence point is

(A) 24.96 mL
(B) 25.00 mL
(C) 25.04 mL
(D) 25.14 mL
(E) 25.50 mL

56. Of the following pairs of acids and conjugate bases, which should be used to prepare a buffer solution whose pH is approximately 5.0 ?

(A) Phosphoric acid ($K_{a_1} = 7.1 \times 10^{-3}$). .sodium dihydrogen phosphate
(B) Acetic acid ($K_a = 1.8 \times 10^{-5}$). .sodium acetate
(C) Carbonic acid ($K_{a_1} = 3.5 \times 10^{-7}$). .sodium hydrogencarbonate
(D) Sodium hydrogensulfate ($K_a = 1.2 \times 10^{-2}$). . sodium sulfate
(E) Boric acid ($K_a = 5 \times 10^{-10}$). .sodium borate

57. Which of the following solids is NOT used as a primary standard in chemical analysis?

(A) Sodium hydroxide
(B) Sodium thiosulfate
(C) Sodium carbonate
(D) Sodium oxalate
(E) Potassium hydrogenphthalate

58. An advantage of high-performance liquid chromatography (HPLC) over gas chromatography (GC) for the separation and measurement of compounds of high molecular weight is that

(A) the sensitivity of HPLC detectors increases as the molecular weights of the compounds increase
(B) HPLC systems are always operated under constant conditions of eluant temperature and composition
(C) the preparation of volatile derivatives is not necessary in HPLC
(D) HPLC columns and detectors are simpler and less expensive
(E) the effectiveness of HPLC columns in separating compounds increases as the molecular weights of the compounds increase

59. At the triple point of water, which of the following relationships for chemical potentials is correct?

(A) $\mu(g) = \mu(l) = \mu(s)$
(B) $\mu(g) \neq \mu(l) \neq \mu(s)$
(C) $\mu(g) \neq \mu(l) = \mu(s)$
(D) $\mu(g) = \mu(l) \neq \mu(s)$
(E) $\mu(l) \neq \mu(g) = \mu(s)$

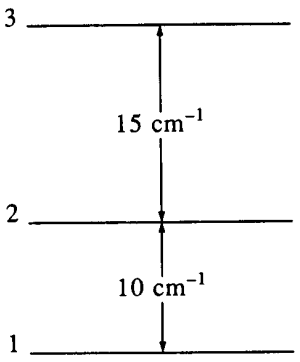
60. In the crystal structure of NaCl, the coordination number of Na^+ is

(A) 2 (B) 4 (C) 6 (D) 8 (E) 12

61. The pH of a 0.01-molar solution of an acid HA is 5. What is the value for the ionization constant of the acid?

(A) 10^{-2}
(B) 10^{-5}
(C) 10^{-7}
(D) 10^{-8}
(E) 10^{-10}

62.



For the energy-level diagram above, what is the wave number of the transition from level 1 to level 3 ? (Wave number, $\tilde{\nu}$, is the reciprocal of wavelength: $\tilde{\nu} = \frac{1}{\lambda} = \frac{\nu}{c}$.)

(A) 150 cm^{-1}
(B) 25 cm^{-1}
(C) 5.0 cm^{-1}
(D) 3.0 cm^{-1}
(E) 0.17 cm^{-1}

63. For a spontaneous process in an isolated system, which of the following is true concerning the entropy change of the system?

(A) It is always zero.
(B) It is always positive.
(C) It is always negative.
(D) It is positive only if the process is exothermic.
(E) More information is required for a prediction of the entropy change.

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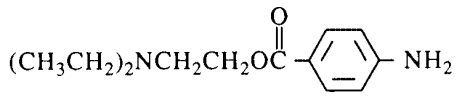
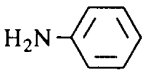
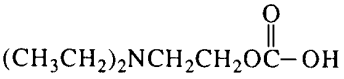
64. 

Novocaine

Which of the compounds below is obtained by the hydrolysis of novocaine with aqueous NaOH?

(A) 

(B) 

(C) $(CH_3CH_2)_2NH$

(D) $(CH_3CH_2)_2NCH_2CH_2OH$

(E) $(CH_3CH_2)_3N$

65. The term electrophile is an appropriate description for all of the following EXCEPT

(A) NO_2^+
(B) BH_3
(C) $(CH_3)_3C^+$
(D) NH_3
(E) $AlCl_3$

66. $NCCH_2CH_2CN \longrightarrow HOOCCH_2CH_2COOH$

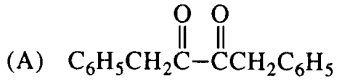
Which of the following terms describes a useful method of carrying out the reaction above?

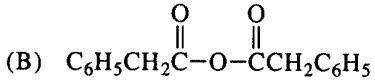
(A) Reduction
(B) Acylation
(C) Hydrolysis
(D) Alkylation
(E) Esterification

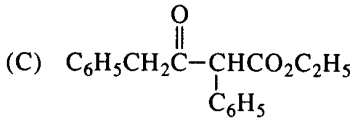
67. Which of the following combinations describes the effect of a nitro group ($-NO_2$) as a substituent in electrophilic aromatic substitution?

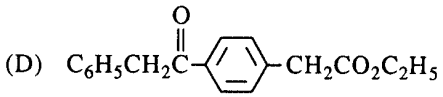
(A) Strongly activating, *ortho-para* directing
(B) Weakly activating, *meta* directing
(C) Weakly deactivating, *ortho-para* directing
(D) Strongly deactivating, *ortho-para* directing
(E) Strongly deactivating, *meta* directing

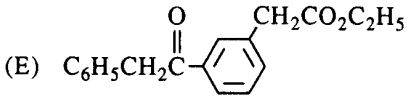
68. The Claisen condensation of two molecules of ethyl phenylacetate, $C_6H_5CH_2CO_2C_2H_5$, in the presence of sodium ethoxide leads to which of the following products?

(A) 

(B) 

(C) 

(D) 

(E) 

69. The density of NaCl(*s*) is 2.17 grams per cubic centimeter. What is the volume occupied by 1.00 mole of sodium chloride?

(A) 3.71×10^{-2} cm^3
(B) 27.0 cm^3
(C) 37.1 cm^3
(D) 58.5 cm^3
(E) 371 cm^3

70. Which of the following is the strongest acid in water?

(A) H_3BO_3
(B) NH_3
(C) H_2S
(D) HClO
(E) $HClO_4$

GO ON TO THE NEXT PAGE.

71. $Hg_2Cl_2(s) + 2\ NH_3(aq) \rightleftarrows HgNH_2Cl(s) + Hg(l) + NH_4^+(aq) + Cl^-(aq)$

Which of the following conclusions can be drawn from the equation above?

(A) Chloride ions have undergone oxidation.
(B) Nitrogen in some of the ammonia molecules has been reduced and the rest of the nitrogen has been oxidized.
(C) The nitrogen in all of the ammonia molecules has undergone reduction.
(D) The reaction is not an oxidation-reduction reaction.
(E) Mercury(I) has undergone both oxidation and reduction.

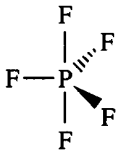
---

72. $3\ NH_4^+ + BiN(s) \longrightarrow Bi^{3+} + 4\ NH_3$

The reaction above occurs in liquid ammonia. In this reaction the ammonium ion behaves as

(A) a catalyst
(B) a reducing agent
(C) an acid
(D) a base
(E) an oxidizing agent

73.



What is the point group symmetry of PF_5, illustrated above?

(A) C_{2v}
(B) C_{3v}
(C) D_{3h}
(D) T_d
(E) O_h

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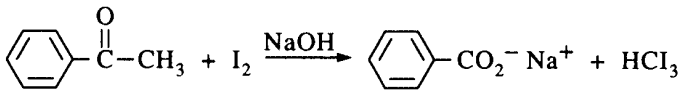
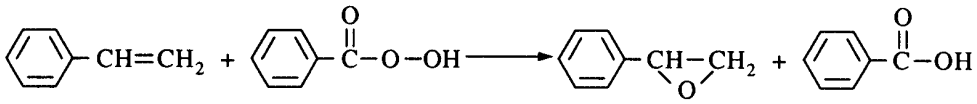
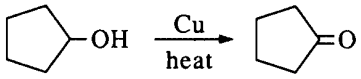
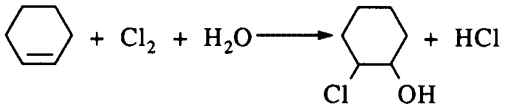
74. In which of the reactions below is the first compound in the equation NOT oxidized?

(A) 

(B) 

(C) 

(D) $CH_3CH{=}O + H_2N{-}OH \longrightarrow CH_3CH{=}NOH + H_2O$

(E) 

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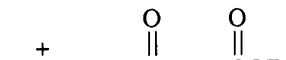
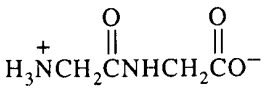
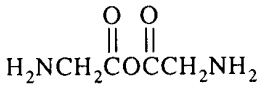
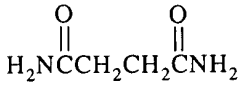
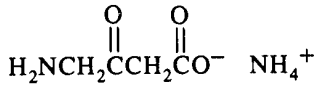
75. Which of the following represents the correct structure for the dipeptide glycylglycine (Gly—Gly)?

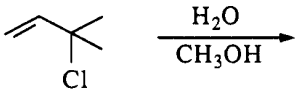
(A) 

(B) 

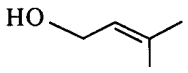
(C) 

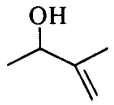
(D) 

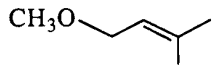
(E) 

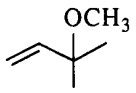
76. 

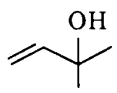
Which of the following is an UNLIKELY product of the reaction above?

(A) 

(B) 

(C) 

(D) 

(E) 

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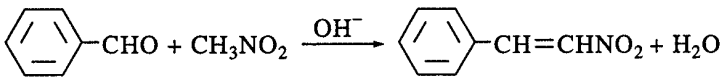
77. 

Which of the following best describes a key step in the mechanism for the reaction above?

(A) Nucleophilic attack by a resonance-stabilized carbanion at a carbonyl carbon
(B) Electrophilic attack by a Lewis acid at a carbonyl carbon
(C) Free radical substitution at a carbonyl carbon
(D) Carbene insertion at a carbonyl carbon
(E) Nucleophilic aromatic substitution

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78. Which of the following carbonyl compounds can be expected to undergo nucleophilic acyl substitution LEAST readily?

(A) $CH_3C(=O)-Cl$

(B) $CH_3C(=O)-O-C(=O)-CH_3$

(C) $CH_3C(=O)-OCH_3$

(D) $CH_3C(=O)-NH_2$

(E) $CH_3C(=O)-H$

79. The density of nitrogen at 0°C and 1 atmosphere is most nearly equal to which of the following quantities?

(A) 0.001 gram/liter
(B) 0.01 gram/liter
(C) 0.1 gram/liter
(D) 1 gram/liter
(E) 10 grams/liter

80. Exact solutions of the Schrödinger equation CANNOT be obtained for a

(A) harmonic oscillator
(B) particle in a box
(C) rigid rotor
(D) hydrogen atom
(E) helium atom

81. The wave functions Ψ_1 and Ψ_2 are orthogonal if which of the following is true?

(A) $\int \Psi_1^* \Psi_1 \, d\tau = 1$

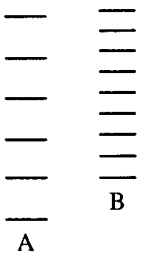
(B) $\int \Psi_1^* \Psi_2 \, d\tau < 0$

(C) $\int \Psi_1^* \Psi_2 \, d\tau = 0$

(D) $\int \Psi_1^* \Psi_2 \, d\tau = 1$

(E) $\int \Psi_2^* \Psi_2 \, d\tau = 1$

82.



Which of the following statements correctly describes the equilibrium positions of the reaction $A \rightleftarrows B$ for which the ground and excited states of the reactant and product are shown above?

(A) A predominates at both low and high temperatures.
(B) B predominates at both low and high temperatures.
(C) A predominates at low temperatures, B at high temperatures.
(D) B predominates at low temperatures, A at high temperatures.
(E) The reaction is nearly temperature-independent, and both A and B are present in approximately equal amounts at both low and high temperatures.

83. If pressure has no effect on the transition temperature between two crystalline forms of matter, the two forms have the same molar

(A) volume
(B) energy
(C) enthalpy
(D) entropy
(E) heat capacity

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84. Which of the following carbonate species would be present in significant concentrations in a solution of carbonic acid at pH 10? (For carbonic acid, $pK_{a_1} = 6.46$, $pK_{a_2} = 10.16$.)

(A) H_2CO_3 only

(B) HCO_3^- only

(C) CO_3^{2-} only

(D) H_2CO_3 and HCO_3^-

(E) HCO_3^- and CO_3^{2-}

85. Which of the following is the most direct and rapid instrumental method for identifying organic functional groups?

(A) Visible absorption spectroscopy
(B) Atomic absorption spectroscopy
(C) Electron spin resonance spectroscopy
(D) Infrared spectroscopy
(E) Microwave spectroscopy

86. If the signal-to-noise ratio for a recorded spectrum is 5, what is the signal-to-noise ratio for the average of 16 spectra recorded in the same manner?

(A) 4
(B) 5
(C) 20
(D) 40
(E) 80

87. The ionic strength of a solution depends on which of the following?

I. The charges on the ions
II. The concentrations of the ions
III. The sizes of the ions

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

88. For gas-phase reactions in which rate-determining steps involve collisions, reaction rates increase with increasing temperature primarily because

(A) more collisions occur because the potential energy barrier is lowered
(B) more collisions have sufficient energy to overcome the potential energy barrier
(C) the viscosity of the gas increases
(D) the efficiency of the catalyst is increased
(E) the concentration of molecules increases

89. The observation that electrons scatter from the surface of metallic nickel to form a diffraction pattern shows that electrons

(A) behave like waves
(B) behave like particles
(C) have charge
(D) have spin
(E) have mass

90. The half-life for a first-order reaction involving reactant R is 70. seconds. The initial concentration of R is 1.0 molar. The concentration of R after 35 seconds is

(A) 0.25 *M* (B) 0.50 *M* (C) 0.71 *M* (D) 0.75 *M* (E) 0.90 *M*

91. The types of energy levels that are evenly spaced include which of the following?

I. Rotational (rigid rotator)
II. Vibrational (harmonic oscillator)
III. Electronic (Born-Oppenheimer approximation)

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

92. $$2\ I_2(g) \xrightarrow{k} 2\ I(g) + I_2(g)$$

If the collisional dissociation of I_2 at high temperatures proceeds by the elementary process above, the rate of formation of $I(g)$ is given by which of the following?

(A) $\frac{d[I]}{dt} = 2k[I_2]^{\frac{1}{2}}$

(B) $\frac{d[I]}{dt} = k[I]^2$

(C) $\frac{d[I]}{dt} = 2k[I_2]^2$

(D) $\frac{d[I]}{dt} = 2k\frac{[I_2]^2}{[I]}$

(E) $\frac{d[I]}{dt} = k\frac{[I]^2}{[I_2]}$

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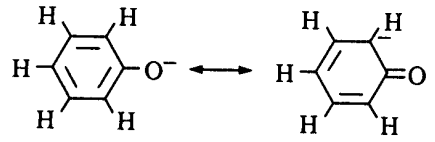
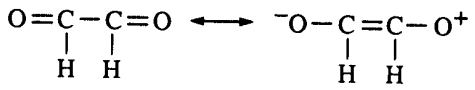
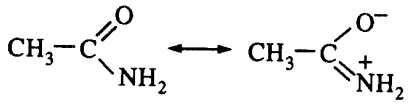
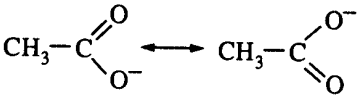
93. In which of the following cases does resonance contribute LEAST toward stabilization?

(A) 

(B) 

(C) 

(D) 

(E) 

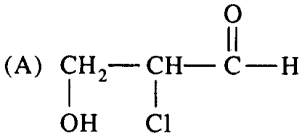
94. An unknown organic substance of molecular formula $C_3H_5O_2Cl$ was found to exhibit the following spectral properties:

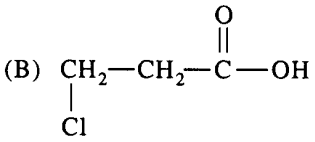
IR: (dilute CCl_4 solution)
2,900 cm^{-1} (broad); 1,710 cm^{-1} (strong)

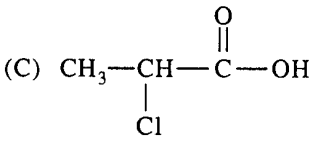
UV: 209 nm (ε 37) (dioxane)

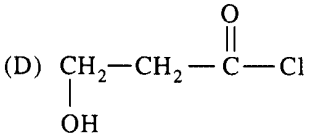
NMR: (CCl_4 solution)
singlet (area 1) at δ 12.0
triplet (area 2) at δ 3.7
triplet (area 2) at δ 2.8

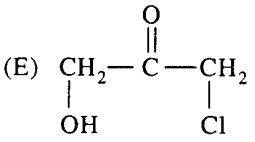
Which of the following structural formulas is consistent with these data?

(A) 

(B) 

(C) 

(D) 

(E) 

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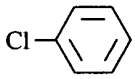
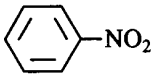
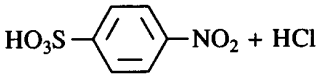
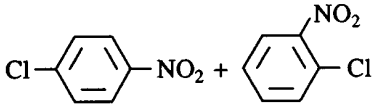
95.

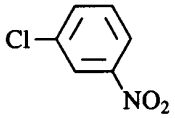


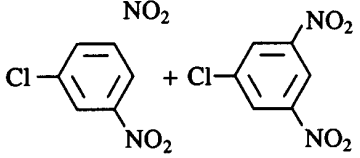
Nitration of chlorobenzene, shown above, with a mixture of nitric and sulfuric acids yields which of the following as the major product or products?

(A) 

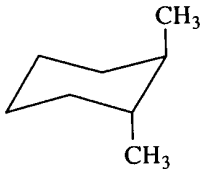
(B) 

(C) 

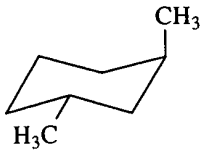
(D) 

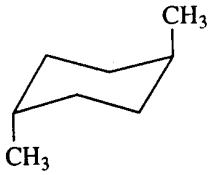
(E) 

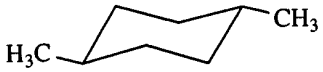
96. Which of the following structures is the most stable?

(A) 

(B) 

(C) 

(D) 

(E) 

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97. Silicates, silicone polymers, and silica share a common property in that they all have

(A) catalytic power for hydrogenation
(B) a sheet structure
(C) a linear chair structure
(D) Si-Si bonds
(E) Si-O bonds

98. Which of the following processes defines the lattice energy of NaCl?

(A) $Na(s) + \frac{1}{2} Cl_2(g) \longrightarrow NaCl(s)$

(B) $Na(g) + Cl(g) \longrightarrow NaCl(s)$

(C) $Na(g) + Cl(g) \longrightarrow NaCl(g)$

(D) $Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$

(E) $Na^+(g) + Cl^-(g) \longrightarrow NaCl(g)$

99. An atom of which of the following elements has the largest atomic radius?

(A) Be
(B) Mg
(C) Al
(D) Cl
(E) K

100. Which of the following molecules is the strongest Lewis acid?

(A) NF_3

(B) SbF_5

(C) NaCl

(D) PCl_3

(E) $SnCl_2$

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101. All of the following are examples of hard acids EXCEPT

(A) H^+

(B) BF_3

(C) Na^+

(D) Mg^{2+}

(E) Tl^+

102. When butanal, $CH_3CH_2CH_2CHO$, is treated with NaOH in ethanol, which of the following is produced?

(A) $CH_3CH_2CH_2CH{=}C(CH_3)CH_2CHO$

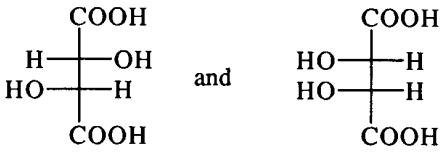
(B) $CH_3CH_2CH_2CH(OH)CH(CH_3)CH_2CHO$

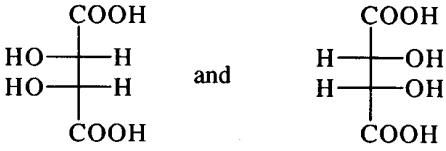
(C) $CH_3CH_2CH_2CH(OH)CH_2CH_2CH_2CHO$

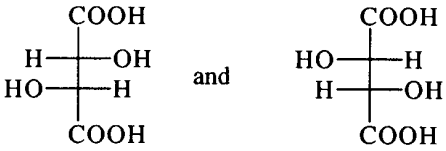
(D) $CH_3CH_2CH_2CH(OH)CH(CHO)CH_2CH_3$

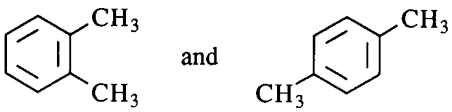
(E) $CH_3CH{=}CHCHO$

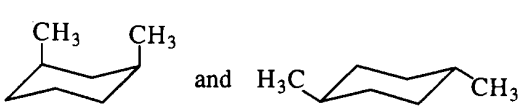
103. In which of the following pairs are the compounds diastereoisomers?

(A)  and

(B)  and

(C)  and

(D) 

(E) 

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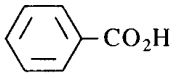
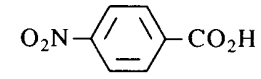
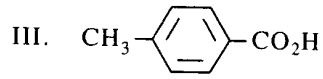
104. I.  II.  III. 

Which of the following best expresses the relative acidities of the substituted benzoic acids shown above?

(A) I > II > III
(B) II > I > III
(C) II > III > I
(D) III > I > II
(E) III > II > I

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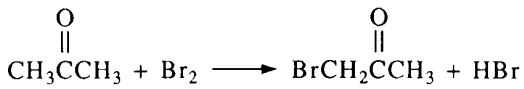
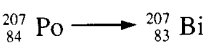
105. 

The bromination of acetone shown above is autocatalytic (it is initially slow but speeds up as the reaction proceeds) because

(A) HBr reacts with Br_2 to give a more reactive brominating agent
(B) the product bromoketone begins to precipitate from solution
(C) the product bromoketone helps to remove the hydrogen from acetone, thus catalyzing the reaction
(D) Br_2 tends to dissociate into the more reactive bromine atoms as its concentration decreases
(E) the conversion of acetone to its enol is catalyzed by the product HBr

106. Which of the following statements best describes a key step in the mechanism of the reaction between benzene and bromine in the presence of $FeBr_3$?

(A) A bromide ion attacks benzene in the slow step.
(B) $FeBr_3$ forms a π-complex with benzene.
(C) A complex of $FeBr_3$ and Br_2 reacts with benzene.
(D) Br_2 adds to a double bond of benzene.
(E) In a concerted process, Br_2 attacks benzene, displacing a proton and producing bromobenzene.

107. 

The transmutation of the element polonium to the element bismuth, as shown above, can occur through which of the following nuclear reactions?

I. Alpha particle emission
II. Positron emission
III. Electron capture

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

108. A substance containing A, B, and C ions crystallizes in a unit cell. A ions are at each of the corners, B ions are at the center of each face, and C ions are at the centers of each edge. What is the empirical formula of the substance?

(A) ABC
(B) AB_3C_3
(C) $A_3B_3C_3$
(D) $A_4B_3C_6$
(E) $A_8B_6C_{12}$

GO ON TO THE NEXT PAGE.

109. Which of the following reacts with water to form hydrogen gas?

(A) $Be(OH)_2$
(B) P_2O_5
(C) SO_3
(D) CsI
(E) NaH

110. According to the 18-electron rule, which of the following compounds would be expected to be unstable? (Atomic numbers: V = 23, Mn = 25, Fe = 26, Ni = 28, Co = 27; Ph = phenyl)

(A) $V(CO)_6^-$
(B) $Fe(CO)_3(PPh_3)_2$
(C) $Ni(CO)_4$
(D) $Co(CO)_4$
(E) $Mn(CO)_6^+$

111. What is the oxidation state of cobalt in $[Co(NH_3)_4(H_2O)Br](NO_3)_2$?

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

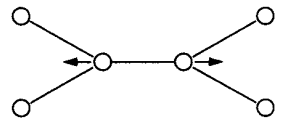
112. The vibrational transition v = 1 to v = 2 in HCl gives rise to a line that is much less intense than the line from the v = 0 to v = 1 transition at 20°C. The main reason for this is that the

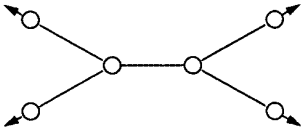
(A) v = 1 to v = 2 transition is forbidden
(B) v = 1 state has a smaller dipole moment
(C) v = 1 state has more rotational states than the v = 0 state
(D) v = 1 to v = 2 transition requires more energy
(E) v = 0 state is more populated than the v = 1 state

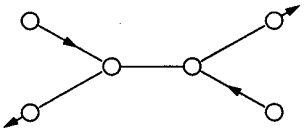
113. The moment of inertia of a heteronuclear diatomic molecule measured from its microwave spectrum provides information about the

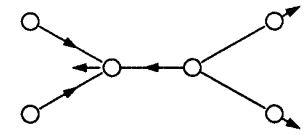
(A) force constant of the bond
(B) vibrational frequency
(C) isotopic abundance
(D) bond strength
(E) bond distance

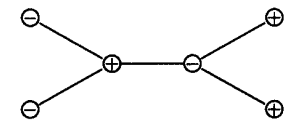
114. Which of the following normal modes of ethylene is active in the infrared?

(A) 

(B) 

(C) 

(D) 

(E) 

115. For monatomic gases, the ratio of the molar heat capacities, C_P/C_V, is equal to

(A) 1
(B) 7/5
(C) 3/2
(D) 5/3
(E) 5/2

116. When an equilibrium mixture of gaseous, colorless N_2O_4 and brown NO_2 is warmed at constant volume, which of the following is correct?

(A) The density remains constant.
(B) The degree of dissociation decreases.
(C) The average molar mass increases.
(D) The pressure decreases.
(E) The color becomes lighter.

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117. A solution has an absorbance of 0.12 in a 2.0-centimeter cell. If the absorptivity of the absorbing species is 2.0 liter · cm^{-1} · $gram^{-1}$, what is its concentration?

(A) 0.030 gram/liter
(B) 0.060 gram/liter
(C) 0.48 gram/liter
(D) 0.030 mole/liter
(E) 0.060 mole/liter

118. Cresol red indicator has two color changes in the pH range 0 - 14.

pH Range	Acid Color	Base Color
0.2 - 1.8	Red	Yellow
7.2 - 8.8	Yellow	Red

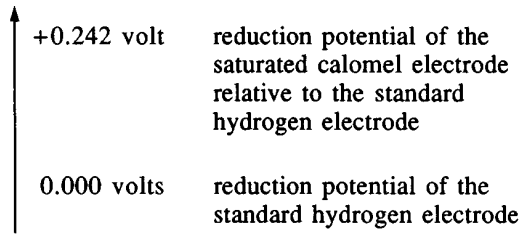
What colors are to be expected in solutions at pH values of 1.0, 6.0, and 9.0 ?

	1.0	6.0	9.0
(A)	Red	Red	Yellow
(B)	Red	Yellow	Yellow
(C)	Orange	Yellow	Red
(D)	Yellow	Orange	Red
(E)	Red	Red	Orange

119. In reverse-phase, high-performance liquid chromatography, the retention time of an analyte is influenced by all of the following EXCEPT the

(A) column length
(B) wavelength of the detector
(C) composition of the mobile phase
(D) composition of the stationary phase
(E) temperature

120.



The reduction potential of the saturated calomel electrode relative to the standard hydrogen electrode is depicted schematically above. The reduction potential of an electrode measured relative to a saturated calomel electrode is –0.694 volt. What is the reduction potential of this same electrode relative to the standard hydrogen electrode?

(A) –0.936 V
(B) –0.452 V
(C) 0.242 V
(D) 0.452 V
(E) 0.936 V

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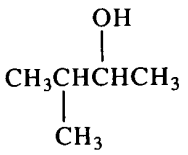
121. Which of the reactions below produces



as the major product?

(A) $(CH_3)_2C{=}CHCH_3 \xrightarrow[2)\ NaOH,\ H_2O]{1)\ HCl}$

(B) $(CH_3)_2C{=}CHCH_3 \xrightarrow[2)\ H_2O_2,\ NaOH]{1)\ B_2H_6}$

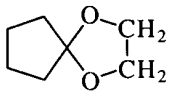
(C) $(CH_3)_2C{=}CHCH_3 \xrightarrow[2)\ NaOH,\ H_2O]{1)\ Br_2,\ H_2O}$

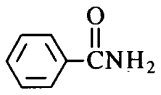
(D) $(CH_3)_2C{=}CHCH_3 \xrightarrow[2)\ NaOH,\ H_2O]{1)\ CH_3CO_2OH}$

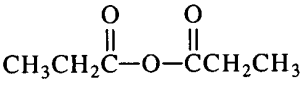
(E) $(CH_3)_2C{=}CHCH_3 \xrightarrow{H_2O,\ H_2SO_4}$

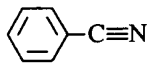
122. Which of the following compounds is resistant to attack by aqueous base but readily hydrolyzes in aqueous acid to a ketone?

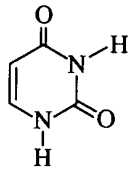
(A) $CH_3CH_2CH_2OCCH_2CH_2CH_3$

(B) 

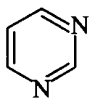
(C) 

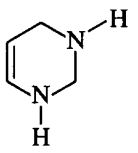
(D) 

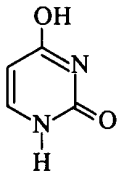
(E) 

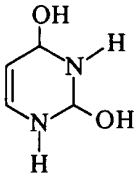
123. 

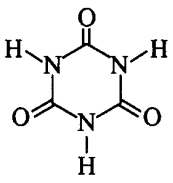
Which of the following compounds is a tautomer of the structure above?

(A) 

(B) 

(C) 

(D) 

(E) 

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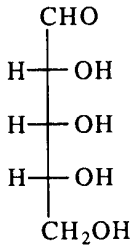
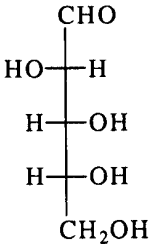
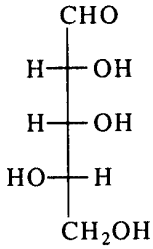
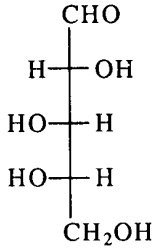
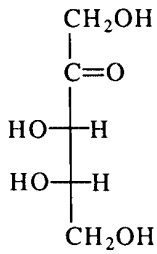
124. A sugar, $C_5H_{10}O_5$, is oxidized by nitric acid to yield an optically inactive dicarboxylic acid, $C_5H_8O_7$. Which of the following is a possible Fischer projection for the sugar?

(A)


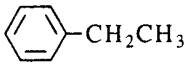
(B)


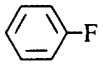
(C)


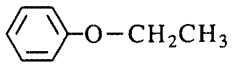
(D)


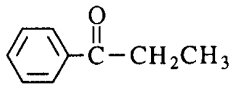
(E)


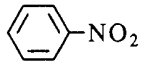
125. Which of the following aromatic compounds most rapidly undergoes electrophilic aromatic substitution?

(A) 

(B) 

(C) 

(D) 

(E) 

126. To which of the following species, all in the gaseous state, must the largest amount of energy be added to remove one electron?

(A) K^+
(B) Cs^+
(C) Ar
(D) Kr
(E) Cl^-

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127. The reaction of which of the following reagents with D_2O will yield ND_3?

(A) TiN
(B) Li_3N
(C) NO_2
(D) N_2
(E) N_2H_4

128. The lowest-lying empty orbital in BF_3 is

(A) a 2*s* orbital localized on B
(B) a 2*p* orbital localized on B
(C) a 2*p* orbital localized on F
(D) an sp^2 orbital localized on B
(E) an sp^3 orbital localized on F

129. Which of the following is the best description of the arrangement of fluorine atoms around the arsenic atom in a molecule of AsF_5?

(A) Trigonal bipyramid
(B) Octahedron
(C) Tetrahedron
(D) Square pyramid
(E) Planar pentagon

130. There are six *d* electrons in Fe^{2+}. If the *d*-orbitals are split by an octahedral ligand field, one should expect to find

(A) no unpaired electrons in the presence of a weak ligand field
(B) two unpaired electrons in the presence of a weak ligand field
(C) two unpaired electrons in the presence of a strong ligand field
(D) four unpaired electrons in the presence of a weak ligand field
(E) four unpaired electrons in the presence of a strong ligand field

131. $Ag^+ + Ce^{4+} \rightleftharpoons Ag^{2+} + Ce^{3+}$

$Tl^+ + Ag^{2+} \longrightarrow Tl^{2+} + Ag^+$

$Tl^{2+} + Ce^{4+} \longrightarrow Tl^{3+} + Ce^{3+}$

Which species is the catalyst in the reaction mechanism given above?

(A) Ag^+
(B) Ce^{3+}
(C) Ce^{4+}
(D) Tl^+
(E) Tl^{2+}

132. According to quantum mechanics, an electron that is incident on a barrier of height V_o (where the energy of the electron is less than V_o) shows which of the following?

(A) There is 100% transmission through the barrier.
(B) There is both transmission and reflection.
(C) The particle is trapped by the barrier.
(D) The particle does not interact with the barrier.
(E) There is 100% reflection from the barrier.

133. $$-\frac{\hbar^2}{2m}(\nabla_1^2+\nabla_2^2)-\frac{e^2}{4\pi\varepsilon_o}\left(\frac{2}{r_1}+\frac{2}{r_2}-\frac{1}{r_{12}}\right)$$

Shown above is the Hamiltonian operator for

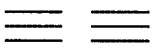
(A) H
(B) H^+
(C) He^+
(D) He
(E) Li^{2+}

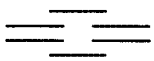
134. At constant temperature and pressure, which of the following is true of spontaneous endothermic reactions?

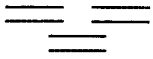
(A) They always have $\Delta H > T\Delta S$.
(B) They always have $\Delta S > 0$.
(C) They sometimes have $\Delta G > 0$.
(D) They cannot occur at high pressures.
(E) They cannot occur at low pressures.

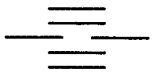
135. Which of the following energy-level diagrams represents the π-electron energies of benzene?

(A) 

(B) 

(C) 

(D) 

(E) 

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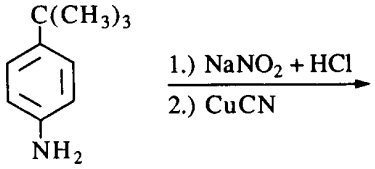
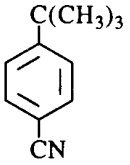
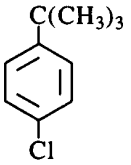
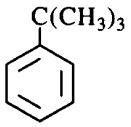
136.

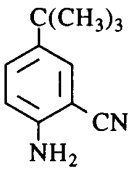


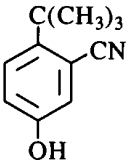
Which of the following compounds is most likely to be formed from the reaction sequence above?

(A) 

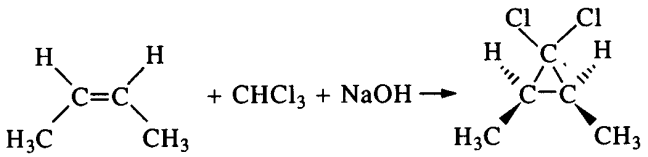
(B) 

(C) 

(D) 

(E) 

137.



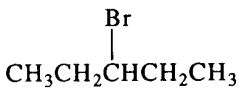
Which of the following is believed to be an intermediate in the stereospecific reaction above?

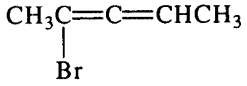
(A) A carbocation
(B) An ylide
(C) A free radical
(D) An alkyne
(E) A carbene

GO ON TO THE NEXT PAGE.

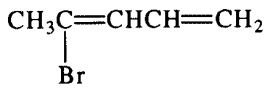
138. Which of the following compounds is chiral?

(A) $BrCH_2CH_2CH_2CH_2CH_3$

(B) 

(C) 

(D) $BrCH{=}CHCH_2CH_2CH_3$

(E) 

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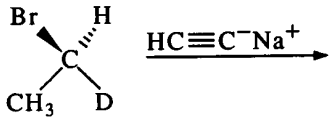
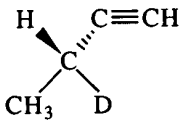
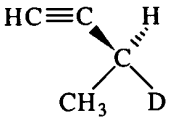
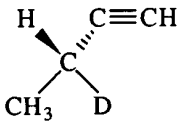
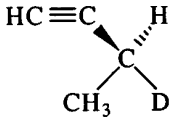
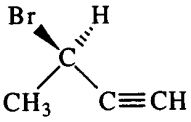
139. 

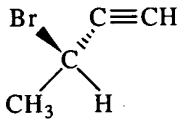
The reaction shown above produces which of the following?

(A)  only

(B)  only

(C) Equal amounts of  and 

(D) 

(E) 

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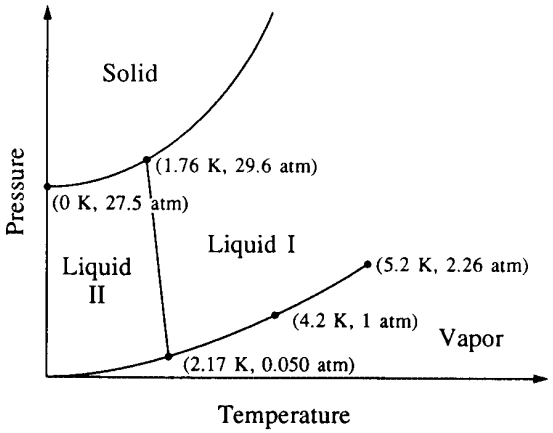
140. Sulfur melts at 113-119°C to form a yellow liquid. As the temperature is raised further, the color darkens and the viscosity becomes quite high. Which of the following statements about these observations is accepted as correct?

(A) The observations are typical of nonmetals when melted.
(B) Ionic bonding develops at higher temperatures.
(C) The original S_8 rings break and long-chain molecules are formed.
(D) The complexity of the molecules is decreased as the temperature rises.
(E) S_λ and S_π form; the former acts as a solute and lowers the vapor pressure of the latter, which acts as the solvent.

141.



According to the schematic phase diagram for helium shown above, the critical temperature for helium is

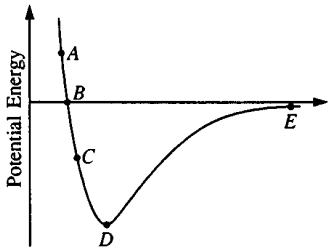
(A) 0 K
(B) 1.76 K
(C) 2.17 K
(D) 4.2 K
(E) 5.2 K

GO ON TO THE NEXT PAGE.

142. If the osmotic pressure of a 0.010-*M* aqueous solution of sucrose at 27°C is 0.25 atmosphere, then the osmotic pressure of a 0.010-*M* aqueous solution of NaCl at 27°C is

(A) 0.062 atm
(B) 0.12 atm
(C) 0.25 atm
(D) 0.50 atm
(E) 1.0 atm

143.



The curve of potential energy *versus* internuclear distance for a diatomic molecule is shown above. The equilibrium internuclear separation is nearest to which point?

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

144. The slope of an isobar (*P* constant) on a plot of a substance's enthalpy (*H*) against its entropy (*S*) is equal to which of the following? (This question can be answered by using the relation $dH = TdS + VdP$ or by dimensional analysis.)

(A) P
(B) V
(C) T
(D) C_P
(E) C_V

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS TEST.

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.

6. TITLE CODE				
2	7	7	5	8
0	0	0	0	0
1	1	1	1	1
●	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	●	5
6	6	6	6	6
7	●	●	7	7
8	8	8	8	●
9	9	9	9	9

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

TEST NAME Chemistry

FORM CODE GR9527

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.

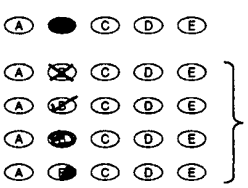
YOU MUST INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination book, but you may write in the book as much as you wish to work out your answers. After you have decided on your response to a question, fill in the corresponding oval on 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.

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Scoring Your Subject Test

Chemistry Test scores typically range from 440 to 920. The range for different editions of a given test may vary because different editions are not of precisely the same difficulty. The differences in ranges among different editions of a given test, however, usually are small. This should be taken into account, especially when comparing two very high scores. The score conversion table on page 49 shows the score range for this edition of the test only.

The worksheet on page 48 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. This is the adjustment made for guessing. 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 75 questions and incorrect answers to 46. Dividing 46 by 4 yields 11.5. Subtracting 11.5 from 75 equals 63.5, which is rounded to 64. The raw score of 64 corresponds to a scaled score of 640.

Worksheet for the Chemistry Test, Form GR9527 Only
Answer Key and Percentages* of Examinees Answering Each Question Correctly

QUESTION Number	Answer	P+	TOTAL C	I
1	C	74		
2	E	44		
3	D	25		
4	C	70		
5	A	57		
6	A	45		
7	D	85		
8	E	87		
9	A	47		
10	A	82		
11	A	23		
12	E	32		
13	A	73		
14	E	51		
15	A	67		
16	C	39		
17	E	32		
18	C	37		
19	C	80		
20	B	84		
21	A	82		
22	B	64		
23	C	44		
24	D	53		
25	D	27		
26	D	56		
27	B	86		
28	A	22		
29	C	29		
30	D	29		
31	D	46		
32	E	35		
33	D	39		
34	E	35		
35	A	47		
36	B	93		
37	A	45		
38	B	37		
39	A	45		
40	C	49		
41	B	35		
42	B	25		
43	D	82		
44	D	38		
45	E	42		
46	A	54		
47	D	52		
48	A	66		
49	B	33		
50	C	44		

QUESTION Number	Answer	P+	TOTAL C	I
51	E	53		
52	E	57		
53	B	58		
54	A	68		
55	C	50		
56	B	67		
57	A	27		
58	C	59		
59	A	81		
60	C	44		
61	D	38		
62	B	72		
63	B	52		
64	D	57		
65	D	70		
66	C	42		
67	E	62		
68	C	41		
69	B	84		
70	E	72		
71	E	60		
72	C	54		
73	C	49		
74	D	59		
75	B	57		
76	B	41		
77	A	49		
78	E	38		
79	D	41		
80	E	69		
81	C	54		
82	C	55		
83	A	37		
84	E	51		
85	D	94		
86	C	22		
87	C	61		
88	B	85		
89	A	70		
90	C	28		
91	B	19		
92	C	32		
93	B	51		
94	B	67		
95	C	59		
96	E	75		
97	E	59		
98	D	43		
99	E	83		
100	B	29		

QUESTION Number	Answer	P+	TOTAL C	I
101	E	39		
102	D	44		
103	A	58		
104	B	52		
105	E	45		
106	C	36		
107	D	47		
108	B	34		
109	E	78		
110	D	44		
111	C	58		
112	E	52		
113	E	40		
114	D	38		
115	D	26		
116	A	35		
117	A	69		
118	C	44		
119	B	81		
120	B	58		
121	B	49		
122	B	49		
123	C	69		
124	A	36		
125	C	40		
126	A	50		
127	B	44		
128	B	50		
129	A	72		
130	D	42		
131	A	61		
132	B	37		
133	D	45		
134	B	65		
135	C	46		
136	A	38		
137	E	41		
138	C	32		
139	A	48		
140	C	58		
141	E	60		
142	D	36		
143	D	79		
144	C	85		

Correct **(C)** _____

Incorrect **(I)** _____

Total Score:

C – I/4 = _____

Scaled Score (SS) = _____

* The P+ column indicates the percentage of Chemistry Test examinees that answered each question correctly; it is based on a sample of December 1995 examinees selected to represent all Chemistry Test examinees tested between October 1, 1992, and September 30, 1995.

Score Conversions and Percents Below*
for GRE Chemistry Test, Form GR9527 Only

TOTAL SCORE					
Raw Score	Scaled Score	%	Raw Score	Scaled Score	%
143-144	940	98	76-78	690	62
140-142	930	98	73-75	680	60
137-139	920	97	71-72	670	58
135-136	910	96	68-70	660	54
132-134	900	95	65-67	650	52
129-131	890	94	63-64	640	49
127-128	880	93	60-62	630	46
124-126	870	92	57-59	620	43
121-123	860	90	54-56	610	40
119-120	850	89	52-53	600	38
116-118	840	88	49-51	590	34
113-115	830	86	46-48	580	31
111-112	820	85	44-45	570	28
108-110	810	84	41-43	560	25
105-107	800	82	38-40	550	22
103-104	790	80	36-37	540	19
100-102	780	79	33-35	530	17
97-99	770	78	30-32	520	14
95-96	760	76	28-29	510	12
92-94	750	74	25-27	500	9
89-91	740	73	22-24	490	7
87-88	730	71	20-21	480	6
84-86	720	69	17-19	470	4
81-83	710	67	14-16	460	3
79-80	700	64	12-13	450	2
			9-11	440	1
			6-8	430	1
			4-5	420	1
			1-3	410	1
			0	400	1

*Percentage scoring below the scaled score is based on the performance of 12,877 examinees who took the Chemistry Test between October 1, 1992, and September 30, 1995. Due to changes in the test-taking population, the percentile rank data have also changed. To obtain current percentile rank information, visit the GRE Web site at www.gre.org/codelst.html, or contact the GRE Program.