



FORM GR0727

27

GRADUATE RECORD EXAMINATIONS®

CHEMISTRY TEST

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PERIODIC TABLE OF THE ELEMENTS																																																																													
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TABLE OF INFORMATION

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

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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.

Note: Solutions are aqueous unless otherwise specified.

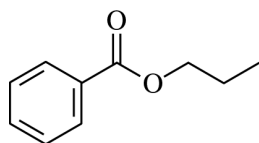
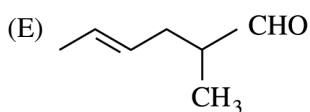
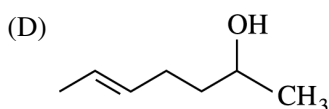
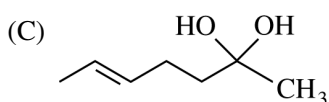
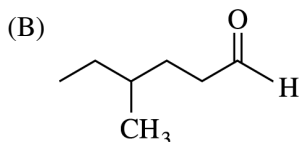
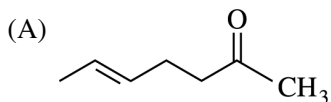
Throughout the test the following symbols have the specified definitions unless otherwise noted.

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)

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



2. According to IUPAC rules, what is the name of the molecule shown above?

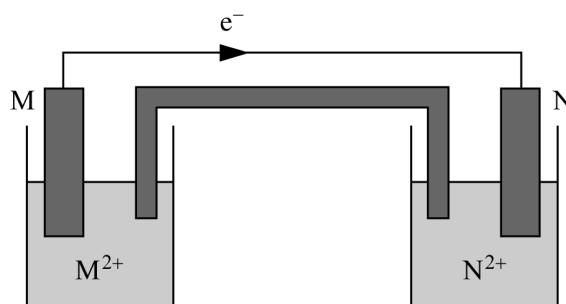
- (A) Benzyl propanoate
- (B) Phenyl propanoate
- (C) Phenyl butanoate
- (D) Propanoyl benzene
- (E) Propyl benzoate

3. Of the following ions, which has the smallest radius?

- (A) K^+
- (B) Ca^{2+}
- (C) Sc^{3+}
- (D) Rb^+
- (E) Sr^{2+}

4. The molecular geometry of thionyl chloride, SOCl_2 , is best described as

- (A) trigonal planar
- (B) T-shaped
- (C) tetrahedral
- (D) trigonal pyramidal
- (E) linear



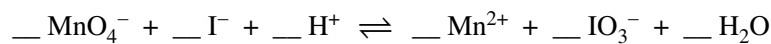
5. Which of the following is true of the cell represented above?

- (A) Metal M is being oxidized.
- (B) Metal N is the reducing agent.
- (C) N^{2+} ions are being oxidized.
- (D) M^{2+} ions are being reduced.
- (E) The cell potential must be zero.

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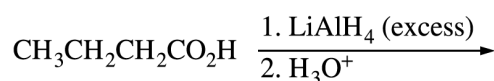
$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

6. Of the following substances, which is likely to have the largest value of the coefficient a in the van der Waals equation of state for real gases shown above?
- (A) H_2
(B) N_2
(C) CH_4
(D) NH_3
(E) CO_2
7. What is the orbital angular momentum quantum number, l , of the electron that is most easily removed when ground-state aluminum is ionized?
- (A) 3
(B) 2
(C) 1
(D) 0
(E) $1/2$








8. When the equation shown above is balanced, which of the following is true?
- (A) The $\text{I}^- : \text{IO}_3^-$ ratio is 3:1.
(B) The $\text{MnO}_4^- : \text{I}^-$ ratio is 6:5.
(C) The $\text{MnO}_4^- : \text{Mn}^{2+}$ ratio is 3:1.
(D) The $\text{H}^+ : \text{I}^-$ ratio is 2:1.
(E) The $\text{MnO}_4^- : \text{IO}_3^-$ ratio is 1:1.

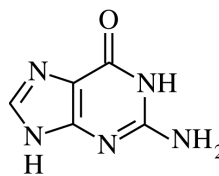
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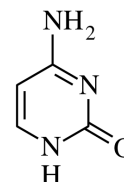
9. Which of the following is the major organic product of the reaction shown above?
- (A) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})_2$
 (B) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$
 (C) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
 (D) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
 (E) $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CH}$

10. All of the following are aromatic EXCEPT

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



Guanine



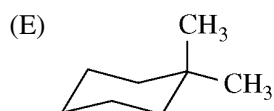
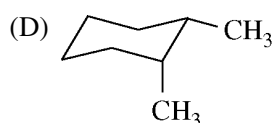
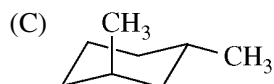
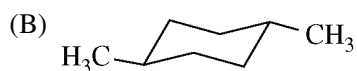
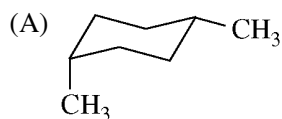
Cytosine

11. In a DNA double-helix, guanine and cytosine bases, shown above, are paired together by

- (A) covalent bonds
 (B) hydrogen bonds
 (C) peptide bonds
 (D) hyperconjugation
 (E) π -stacking

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12. Of the following isomers, which is the most thermodynamically stable?



13. Under constant current electrolysis, how many coulombs would be required to reduce 2 mol of Cu^{2+} to metallic copper?
($\mathcal{F} = 96,500$ coulombs/mol)

- (A) 2
(B) 48,250
(C) 96,500
(D) 193,000
(E) 386,000

[A]	[B]	Initial Rate
0.10 M	0.30 M	$1.5 \times 10^{-4} \text{ M s}^{-1}$
0.20 M	0.30 M	$3.0 \times 10^{-4} \text{ M s}^{-1}$
0.20 M	0.60 M	$12.0 \times 10^{-4} \text{ M s}^{-1}$

14. For the reaction $\text{A} + \text{B} \rightarrow \text{C} + \text{D}$ carried out at constant temperature, the initial rates of reaction given above were found experimentally.

The rate law of this reaction, expressed as a function of reactant concentrations, is

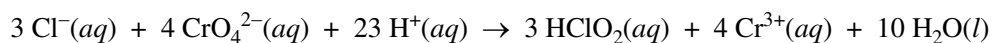
- (A) rate = $k([\text{A}] + [\text{B}])$
(B) rate = $k[\text{A}][\text{B}]$
(C) rate = $k[\text{A}]^2[\text{B}]$
(D) rate = $k[\text{A}][\text{B}]^2$
(E) rate = $k[\text{A}]^2[\text{B}]^4$

15. Which of the following must be true about a binary liquid mixture that obeys Raoult's law?

- I. The partial pressure of each component at equilibrium is proportional to its mole fraction in the liquid mixture.
II. The volume of the mixture is equal to the sum of the volumes of each component before mixing.
III. Intermolecular interactions in the mixture are identical to intermolecular interactions in the pure components.

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

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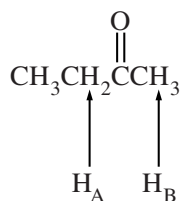


16. In the reaction shown above, $\text{Cl}^-(aq)$ behaves as

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

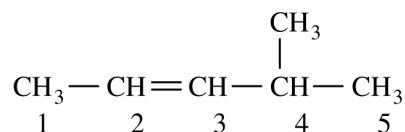
17. Elements with partially filled $4f$ or $5f$ orbitals include all of the following EXCEPT

- (A) Cu
- (B) Gd
- (C) Eu
- (D) Am
- (E) Cm



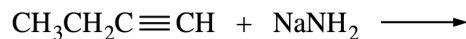
18. Which of the following gives the multiplicities of the signals for the protons designated H_A and H_B in the ^1H NMR spectrum of the compound shown above?

- | $\underline{\text{H}}_A$ | $\underline{\text{H}}_B$ |
|--------------------------|--------------------------|
| (A) Singlet | Singlet |
| (B) Triplet | Doublet |
| (C) Septet | Singlet |
| (D) Quartet | Triplet |
| (E) Quartet | Singlet |



19. In the compound shown above, which hydrogen is most easily abstracted in a free radical bromination reaction?

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



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

- (A) $\text{NaCH}_2\text{CH}_2\text{C}\equiv\text{CH}$
- (B) $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CNH}_2$
- (C) $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CNa}$
- (D) $\begin{array}{c} \text{NH}_2 \\ | \\ \text{CH}_3\text{CH}_2\text{C}=\text{CHNa} \end{array}$
- (E) $\begin{array}{c} \text{NH}_2 \\ | \\ \text{CH}_3\text{CH}_2\text{C}=\text{CH}_2 \end{array}$

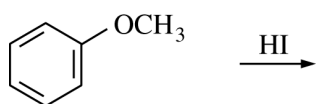
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21. Which of the following is always true of a spontaneous process?
- The process is exothermic.
 - The process does not involve any work.
 - The entropy of the system increases.
 - The internal energy of the system decreases.
 - The total entropy of the system plus surroundings increases.
22. The equation $\Delta H = \Delta U + P\Delta V$ is applicable
- always
 - only for constant pressure processes
 - only for constant temperature processes
 - only for constant volume processes
 - only for constant entropy processes
23. A system that consists of a sample of nitrogen gas behaving as an ideal gas is compressed at a constant temperature. Which of the following is true about w (work) and q (heat transfer) for this process?
- | | w | q |
|-----|-------|-------|
| (A) | > 0 | < 0 |
| (B) | > 0 | > 0 |
| (C) | < 0 | < 0 |
| (D) | < 0 | > 0 |
| (E) | $= 0$ | $= 0$ |
24. What is the maximum number of phases that can be at equilibrium with each other in a three-component mixture?
- 2
 - 3
 - 4
 - 5
 - 6
25. Infrared (IR) spectroscopy is useful for determining certain aspects of the structure of organic molecules because
- all molecular bonds absorb IR radiation
 - IR peak intensities are related to molecular mass
 - most organic functional groups absorb in a characteristic region of the IR spectrum
 - each element absorbs at a characteristic wavelength
 - vibrational transitions are correlated to spin-spin coupling
26. Which of the following statements about nuclear binding energies is NOT true?
- Binding energy per nucleon reaches a maximum for ^{56}Fe .
 - Nuclear binding energies have about the same magnitude as chemical bond energies.
 - Nuclei have slightly less mass than the sum of their component nucleons.
 - The nuclei of heavy elements have more neutrons than protons in order to provide sufficient binding energy to hold the nuclei together.
 - When very light elements undergo exothermic fusion reactions, the released energy arises from an increased binding energy per nucleon in the fusion products.

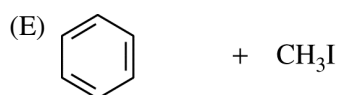
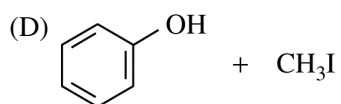
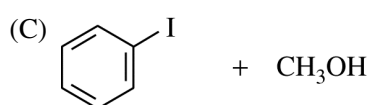
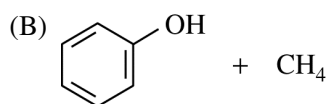
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27. The dissociation energy for a hydrogen-bromine bond is defined as the change in enthalpy, ΔH , for which of the following reactions?
- (A) $2 \text{HBr}(g) \rightarrow \text{H}_2(g) + \text{Br}_2(l)$
 (B) $\text{HBr}(g) \rightarrow \text{H}^+(g) + \text{Br}^-(g)$
 (C) $\text{H}(g) + \text{Br}(g) \rightarrow \text{HBr}(g)$
 (D) $\text{H}_2(g) + \text{Br}_2(l) \rightarrow 2 \text{HBr}(g)$
 (E) $\text{HBr}(g) \rightarrow \text{H}(g) + \text{Br}(g)$
28. A radioactive isotope, which is used in diagnostic imaging, has a half-life of 6.0 hours. If a quantity of this isotope has an activity of $150 \mu\text{Ci}$ when it is delivered to a hospital, how much activity will remain 24 hours after delivery? (μCi = microcuries)
- (A) $150 \mu\text{Ci}$
 (B) $38 \mu\text{Ci}$
 (C) $19 \mu\text{Ci}$
 (D) $9.4 \mu\text{Ci}$
 (E) $4.7 \mu\text{Ci}$
29. The rate, r , of a zero-order chemical reaction $\text{A} \rightarrow \text{B}$ can be expressed as which of the following?
- (A) $r = k \ln[\text{A}]$
 (B) $r = k [\text{A}]^2$
 (C) $r = k [\text{A}]$
 (D) $r = k [\text{A}]^{1/2}$
 (E) $r = k$
30. Which of the following is classified as a conjugate acid-base pair?
- (A) HCl / NaOH
 (B) $\text{H}_3\text{O}^+ / \text{H}_2\text{O}$
 (C) $\text{O}_2 / \text{H}_2\text{O}$
 (D) H^+ / Cl^-
 (E) $\text{NaCl} / \text{NaOH}$
31. An impure sample of K_2O was analyzed by precipitating the potassium as the insoluble tetraphenyl borate salt, $\text{KB}(\text{C}_6\text{H}_5)_4$. The precipitate, $\text{KB}(\text{C}_6\text{H}_5)_4$ had a mass of 1.57 g. The mass of K_2O in the original sample is obtained from which of the following? (Molar masses: $\text{KB}(\text{C}_6\text{H}_5)_4 = 358.3 \text{ g}$ and $\text{K}_2\text{O} = 94.2 \text{ g}$)
- (A) $\frac{(1.57)(94.2)}{(358.3)}$
 (B) $\frac{(358.3)}{(1.57)(94.2)}$
 (C) $\frac{(1.57)(94.2)}{2(358.3)}$
 (D) $\frac{2(1.57)(94.2)}{(358.3)}$
 (E) $\frac{2(358.3)}{(1.57)(94.2)}$

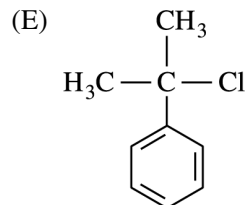
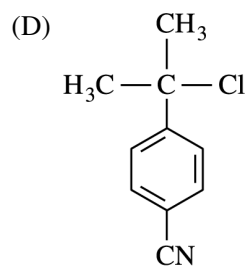
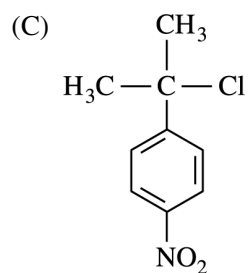
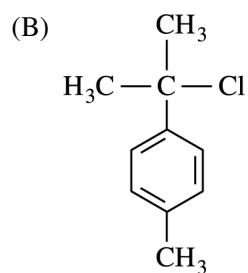
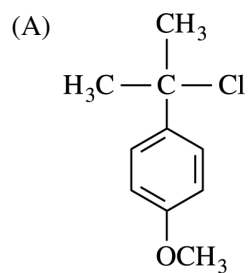
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32. Which of the following are the major products of the reaction shown above?

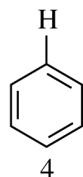
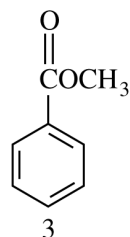
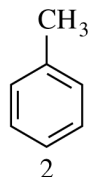
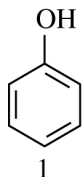
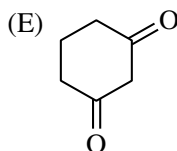
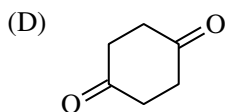
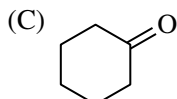
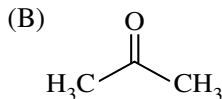
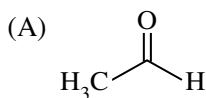


33. Of the following compounds, which has the fastest S_N1 reaction rate with H₂O in acetone?



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34. Of the following, which compound is in equilibrium with the greatest percentage of its enol isomer?



35. In which of the following are the molecules shown above listed in order of increasing reactivity toward electrophilic aromatic substitution?

- (A) 2 < 4 < 1 < 3
 (B) 3 < 2 < 4 < 1
 (C) 3 < 4 < 2 < 1
 (D) 4 < 2 < 1 < 3
 (E) 4 < 3 < 1 < 2

36. Considering 0.1 M aqueous solutions of each of the following, which solution has the lowest pH?

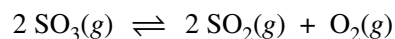
- (A) Na_2CO_3
 (B) Na_3PO_4
 (C) Na_2S
 (D) NaCl
 (E) CH_3COONa

37. Of the following compounds, which has the lowest melting point?

- (A) HCl
 (B) AgCl
 (C) CaCl_2
 (D) CCl_4
 (E) SnCl_4

38. Of the following solutions, which will have the highest ionic strength? (Assume complete dissociation.)

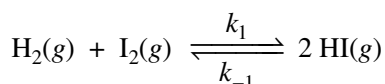
- (A) 0.050 M AlCl_3
 (B) 0.100 M NaCl
 (C) 0.050 M CaCl_2
 (D) 0.100 M HCl
 (E) 0.050 M $\text{Ca}(\text{NO}_3)_2$



39. The K_p for the reaction shown above is 0.26 at 1,000°C and 40.8 at 1,300°C. Which of the following combinations of ΔH and ΔS are most plausible for this reaction at these temperatures?

- | | ΔH | ΔS |
|-----|------------|------------|
| (A) | = 0 | = 0 |
| (B) | > 0 | > 0 |
| (C) | > 0 | < 0 |
| (D) | < 0 | > 0 |
| (E) | < 0 | < 0 |

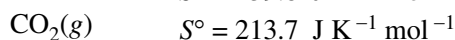
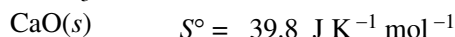
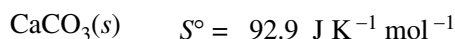
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$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

40. At a given temperature, the forward rate constant, k_1 , for the one-step reaction shown above is $4 \times 10^{-7} \text{ M}^{-1} \text{ s}^{-1}$. Given that the equilibrium constant is 1×10^{-2} , what is the reverse rate constant, k_{-1} ?

- (A) $8 \times 10^{-5} \text{ M}^{-1} \text{ s}^{-1}$
 (B) $4 \times 10^{-5} \text{ M}^{-1} \text{ s}^{-1}$
 (C) $4 \times 10^{-7} \text{ M}^{-1} \text{ s}^{-1}$
 (D) $8 \times 10^{-9} \text{ M}^{-1} \text{ s}^{-1}$
 (E) $4 \times 10^{-9} \text{ M}^{-1} \text{ s}^{-1}$



41. Given the standard molar entropies listed above, the standard reaction entropy, ΔS° , in $\text{J K}^{-1} \text{ mol}^{-1}$, for the decomposition of calcium carbonate into calcium oxide and carbon dioxide is
- (A) $(92.9 + 39.8 + 213.7)$
 (B) $(-92.9 - 39.8 - 213.7)$
 (C) $(-92.9 - 39.8 + 213.7)$
 (D) $(39.8 + 213.7)$
 (E) $(-92.9 + 39.8 + 213.7)$

42. The Rydberg equation given above accurately predicts the UV-visible emission spectrum of the hydrogen atom. A form of the Rydberg equation may also be used to predict the UV-visible emission for all of the following EXCEPT

- (A) hydride ion, H^-
 (B) deuterium atom, D
 (C) tritium atom, T
 (D) helium cation, He^+
 (E) beryllium cation, Be^{3+}

$$\text{p}K_{a1} = 2.95$$

$$\text{p}K_{a2} = 6.79$$

43. Phthalic acid, $(\text{COOH})\text{C}_6\text{H}_4(\text{COOH})$, is a weak, diprotic acid with dissociation constants above. The pH of an aqueous solution of potassium acid phthalate, $(\text{COOH})\text{C}_6\text{H}_4(\text{COO}^- \text{K}^+)$, is closest to

- (A) 9.74
 (B) 7.00
 (C) 6.79
 (D) 4.87
 (E) 2.95

44. Which of the following is true for Br_2 at standard temperature and pressure?

- (A) It is a colorless gas.
 (B) It is a red-brown volatile liquid.
 (C) It is a colorless volatile liquid.
 (D) It is a yellow metallic solid.
 (E) It is a yellow insulating solid.

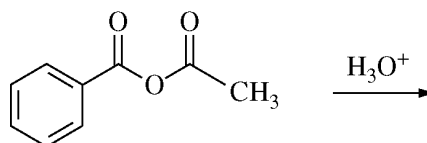
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45. On the basis of oxidation-reduction potential, which of the following is most likely to occur?

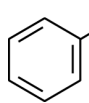
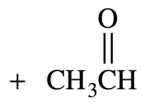
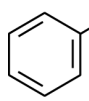
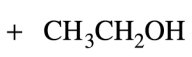
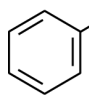
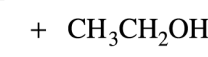
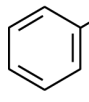
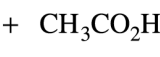
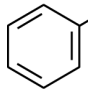
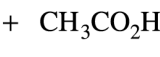
- (A) $\text{Al}(s) + 3 \text{NaNO}_3(aq) \rightarrow 3 \text{Na}(s) + \text{Al}(\text{NO}_3)_3(aq)$
- (B) $\text{Zn}(s) + 2 \text{Ag}(\text{NO}_3)(aq) \rightarrow 2 \text{Ag}(s) + \text{Zn}(\text{NO}_3)_2(aq)$
- (C) $\text{Pb}(s) + \text{Ca}(\text{NO}_3)_2(aq) \rightarrow \text{Ca}(s) + \text{Pb}(\text{NO}_3)_2(aq)$
- (D) $\text{Pb}(s) + 2 \text{LiNO}_3(aq) \rightarrow 2 \text{Li}(s) + \text{Pb}(\text{NO}_3)_2(aq)$
- (E) $\text{Ca}(s) + 2 \text{NaNO}_3(aq) \rightarrow 2 \text{Na}(s) + \text{Ca}(\text{NO}_3)_2(aq)$

46. Cobalt-60 is used in the radiation therapy of cancer and can be produced by bombardment of cobalt-59 with which of the following?

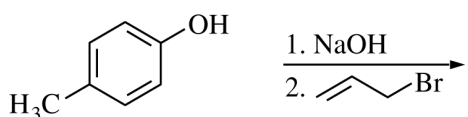
- (A) Neutrons
- (B) Alpha particles
- (C) Beta particles
- (D) X-rays
- (E) Gamma rays



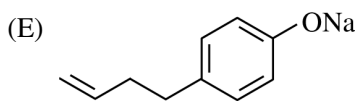
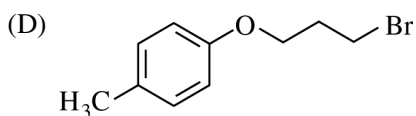
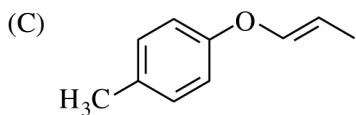
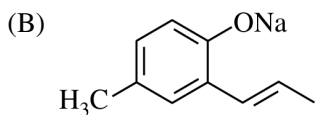
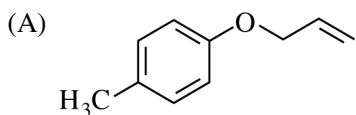
47. Which of the following are the products of the reaction shown above?

- (A)  + 
- (B)  + 
- (C)  + 
- (D)  + 
- (E)  + 

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48. What is the product of the reaction shown above for *para*-cresol?



49. At 25°C, the maximum amount of PbI_2 that can be dissolved in 1.00 L of pure water is 1.0 mmol. Assuming complete dissociation, the solubility product, K_{sp} , for lead iodide at 25°C is

- (A) 1.0×10^{-3}
 (B) 1.0×10^{-6}
 (C) 1.0×10^{-9}
 (D) 2.0×10^{-9}
 (E) 4.0×10^{-9}

50. Which of the following must be true if the wavefunction $\psi(x)$ is normalized?

(A) $\psi^*(x)\psi(x) = 0$

(B) $\psi^*(x)\psi(x) = 1$

(C) $\int_{-\infty}^{+\infty} \psi^*(x)\psi(x)dx = 0$

(D) $\int_{-\infty}^{+\infty} \psi^*(x)\psi(x)dx = 1$

(E) $\frac{d^2\psi(x)}{dx^2} = 1$

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51. If $\psi(r)$ is the wavefunction for a $1s$ electron, the average distance from the nucleus for the electron is equal to

(A) $\psi^*(r)\psi(r)$

(B) $\int_0^r \psi^*(r)\psi(r) dr$

(C) $\int_0^\infty \psi^*(r)\psi(r) dr$

(D) $\psi^*(r)\hat{r}\psi(r)$

(E) $4\pi\int_0^\infty \psi^*(r)\hat{r}\psi(r) r^2 dr$

52. Which of the following experimental observations were explained by Planck's quantum theory?

- (A) Blackbody radiation curves
- (B) Emission spectra of diatomic molecules
- (C) Electron diffraction patterns
- (D) Temperature dependence of reaction rates
- (E) Pressure dependence of boiling points

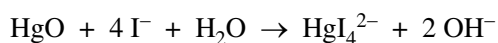
54. The anhydride of $\text{Ba}(\text{OH})_2$ is

- (A) BaH_2
- (B) BaOH
- (C) Ba
- (D) BaO_2
- (E) BaO

53. The $+1$ oxidation state is more stable than the $+3$ oxidation state for which group 13 element?

- (A) B
- (B) Al
- (C) In
- (D) Ga
- (E) Tl

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55. A 0.217 g sample of HgO (molar mass = 217 g) reacts with excess iodide ions according to the reaction shown above. Titration of the resulting solution requires how many mL of 0.10 M HCl to reach equivalence point?

(A) 1.0 mL
 (B) 10 mL
 (C) 20 mL
 (D) 50 mL
 (E) 100 mL

56. The Hamiltonian operator for a particle in a one-dimensional box, whose potential is zero inside the box and infinite outside the box, is

(A) $\hat{H} = \frac{-\hbar^2}{2m} \frac{d^2}{dx^2}$
 (B) $\hat{H} = \frac{-\hbar^2}{2mR^2} \frac{d^2}{d\phi^2} + \frac{a\phi}{\pi}$
 (C) $\hat{H} = \frac{-\hbar^2}{2m} \frac{d^2}{dx^2} + \frac{1}{2}kx^2$
 (D) $\hat{H} = \frac{-\hbar^2}{2m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) - \frac{Ze^2}{r}$
 (E) $\hat{H} = \frac{-\hbar^2}{2mR^2} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right)$

57. The normal modes of a carbon dioxide molecule that are infrared-active include which of the following?

I. Bending
 II. Symmetric stretching
 III. Asymmetric stretching

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

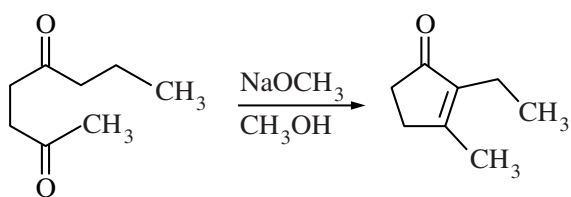
58. Which of the following types of spectroscopy is a light-scattering technique?

(A) Nuclear magnetic resonance
 (B) Infrared
 (C) Raman
 (D) Ultraviolet-visible
 (E) Electron paramagnetic resonance

59. When a certain metal is irradiated with radiation of frequency $5.5 \times 10^{14} \text{ s}^{-1}$, electrons are ejected. If the work function of the metal is $2.9 \times 10^{-19} \text{ J}$, which of the following expresses the kinetic energy (in joules) of the ejected electrons?

(A) $h(5.5 \times 10^{14} \text{ s}^{-1}) - (2.9 \times 10^{-19} \text{ J})$
 (B) $(2.9 \times 10^{-19} \text{ J}) - h(5.5 \times 10^{14} \text{ s}^{-1})$
 (C) $h(5.5 \times 10^{14} \text{ s}^{-1}) + (2.9 \times 10^{-19} \text{ J})$
 (D) $\frac{h(5.5 \times 10^{14} \text{ s}^{-1})}{(2.9 \times 10^{-19} \text{ J})}$
 (E) $\frac{(2.9 \times 10^{-19} \text{ J})}{h(5.5 \times 10^{14} \text{ s}^{-1})}$

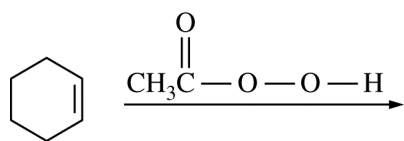
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60. The product of the reaction shown above is produced via which of the following intermediates?

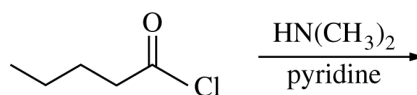
- (A)
- (B)
- (C)
- (D)
- (E)

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

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



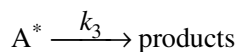
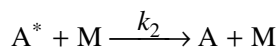
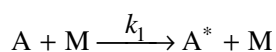
62. What is the product of the reaction shown above?

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

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63. Which of the following procedures tend(s) to minimize the influence of random errors on measured results?
- Signal averaging
 - Use of internal standards
 - Averaging the results from multiple samples
- (A) I only
(B) II only
(C) III only
(D) I and III only
(E) I, II, and III
64. A buffer is made from equal concentrations of a weak acid and its conjugate base. Doubling the volume of the buffer solution by adding water has what effect on its pH ?
- (A) It has little effect.
(B) It significantly increases the pH.
(C) It significantly decreases the pH.
(D) It changes the pH asymptotically to the pK_a of the acid.
(E) It changes the pH asymptotically to the pK_b of the conjugate base.
65. Which of the following is the most common naturally-occurring form in which silicon is found?
- (A) Metallic element
(B) Sulfide
(C) Fluoride
(D) Oxide
(E) Nitride
66. A substance that is NOT generally considered to be a toxic pollutant in water is
- (A) carbonic acid
(B) a halogenated hydrocarbon
(C) lead
(D) mercury
(E) cadmium
67. Which of the following is an n-type semiconductor?
- (A) Silicon
(B) Diamond
(C) Silicon carbide
(D) Arsenic-doped silicon
(E) Gallium-doped silicon
68. Which of the following is lower for argon than for neon?
- (A) Melting point
(B) Boiling point
(C) Polarizability
(D) Heat of vaporization
(E) First ionization energy
69. For EDTA titrations, the analyte solution and the titrant solution are both buffered at the same pH for which of the following reasons?
- The conditional formation constant is affected by pH.
 - The fraction of EDTA in the fully deprotonated Y^{4-} form varies with pH.
 - When EDTA reacts to form a metal complex, H^+ is a product in most cases.
- (A) I only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III
70. The Henry's law constant for CO_2 dissolved in water at $25^\circ C$ is 30.0 atm M^{-1} . The concentration of dissolved CO_2 in a vessel pressurized with 2.0 atm of CO_2 is
- (A) 1.5 M
(B) 0.15 M
(C) 0.067 M
(D) 0.015 M
(E) 0.0067 M

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	<u>Process</u>	<u>Work</u>
System A	Adiabatic	-300 J
System B	Nonadiabatic	-200 J

71. The gas-phase reaction $A \rightarrow \text{products}$ is postulated to proceed by the mechanism shown above, in which A^* is an activated A molecule and M is a chemically inert gas. Assuming the steady-state approximation for A^* , this mechanism yields the rate equation

$$\text{rate} = \frac{k_1 k_3 [M][A]}{k_3 + k_2 [M]}$$

Which of the following is NOT consistent with this mechanism?

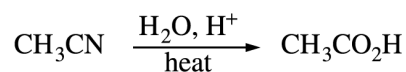
- (A) When the partial pressure of M is very high, the reaction is first order in A .
- (B) When the partial pressure of M is very high, the reaction is first order overall.
- (C) When the partial pressure of M is very low, the reaction is second order overall.
- (D) When the partial pressure of M is very low, the rate is independent of the concentration of A .
- (E) M can be any molecule capable of transferring energy to A upon collision.

72. System A and system B above are identical closed systems that undergo a change of state from the same initial conditions (P_1, V_1, T_1) to the same final conditions (P_2, V_2, T_2), but by a different process. What are ΔU and q for the change in state for system B?

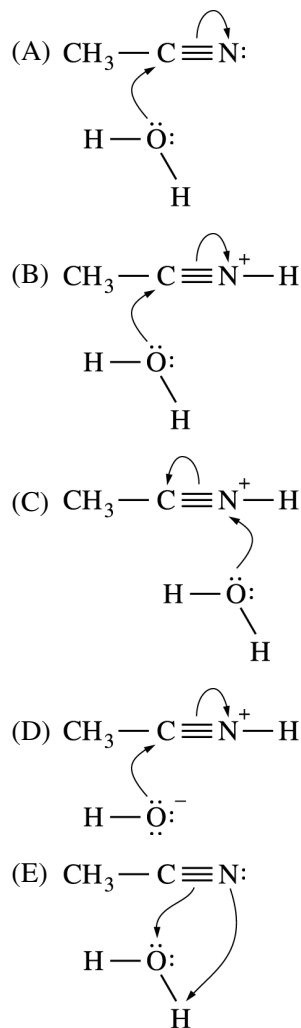
	<u>ΔU(J)</u>	<u>q(J)</u>
(A)	-300	0
(B)	-300	-100
(C)	-100	-100
(D)	0	-300
(E)	200	0

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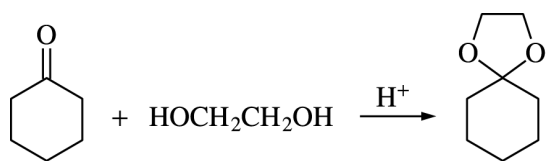
73. Chlorofluorocarbons (CFCs) such as F_3CCl_3 are implicated in the decomposition of stratospheric ozone. Which of the following methods would be best suited to measurement of trace amounts (sub-ppb) of CFCs in an air sample?
- (A) Gas chromatographic separation of the air sample on a capillary column followed by electron capture detection
- (B) Gas chromatographic separation of the air sample on a packed column followed by thermal conductivity detection
- (C) Gas chromatographic separation of the air sample on a capillary column followed by flame ionization detection
- (D) Conversion of the sample of the chlorinated compounds to chloride ions, followed by titration with Ag^+
- (E) Conversion of the sample of the chlorinated compounds to chloride ions, followed by direct measurement of chloride with chloride selective electrode



74. Which of the following best depicts the initial nucleophilic addition step in the acid-catalyzed hydrolysis of acetonitrile shown above?

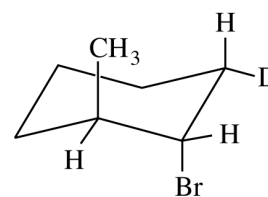


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75. Which of the following is the hemiacetal intermediate in the reaction shown above?

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

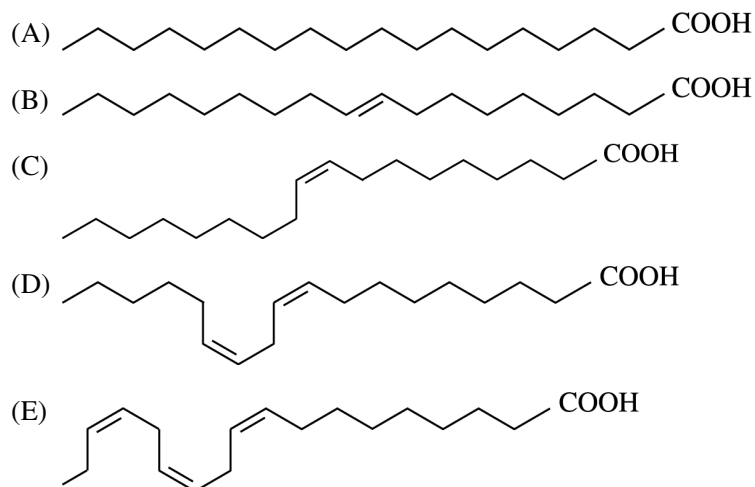


76. What is the major product of an E2 reaction of the compound shown above?

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

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77. Of the following fatty acids, which has the lowest melting point?



78. Of the following compounds, which is LEAST likely to behave as a Lewis acid?

- (A) BeCl_2
- (B) MgCl_2
- (C) ZnCl_2
- (D) SnCl_2
- (E) SnCl_4

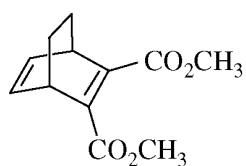
80. Which of the following lists the hydrides of group-14 elements in order of thermal stability, from lowest to highest?

- (A) $\text{PbH}_4 < \text{SnH}_4 < \text{GeH}_4 < \text{SiH}_4 < \text{CH}_4$
- (B) $\text{PbH}_4 < \text{SnH}_4 < \text{CH}_4 < \text{GeH}_4 < \text{SiH}_4$
- (C) $\text{CH}_4 < \text{SiH}_4 < \text{GeH}_4 < \text{SnH}_4 < \text{PbH}_4$
- (D) $\text{CH}_4 < \text{PbH}_4 < \text{GeH}_4 < \text{SnH}_4 < \text{SiH}_4$
- (E) $\text{GeH}_4 < \text{PbH}_4 < \text{SiH}_4 < \text{SnH}_4 < \text{CH}_4$

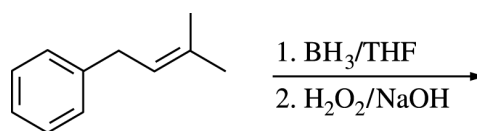
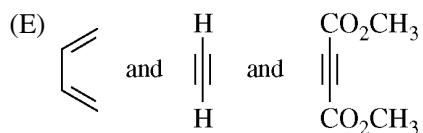
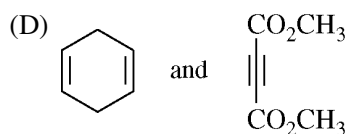
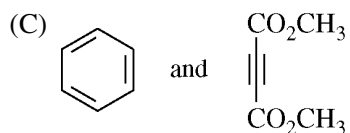
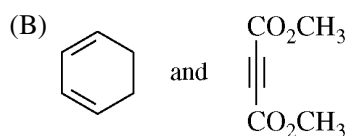
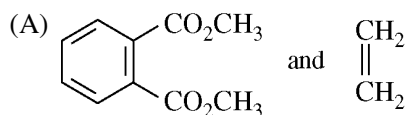
79. The strongest base in liquid ammonia is

- (A) NH_3
- (B) NH_2^-
- (C) NH_4^+
- (D) N_2H_4
- (E) OH^-

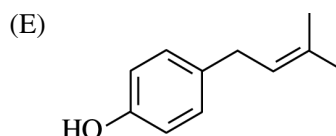
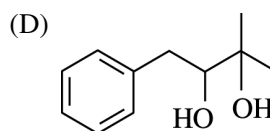
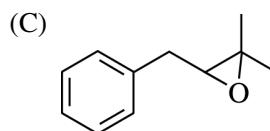
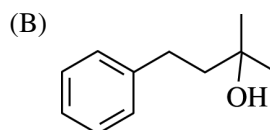
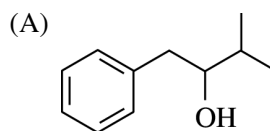
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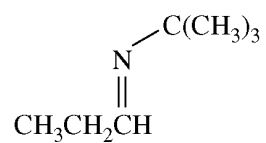
81. Which of the following starting materials could be used in a Diels-Alder reaction to prepare the bicyclic product shown above?



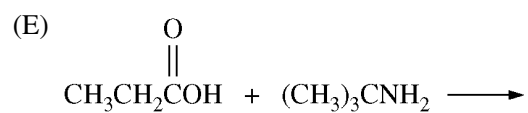
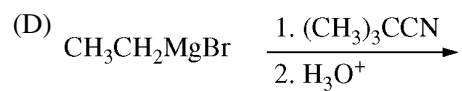
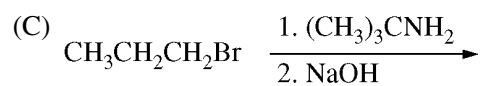
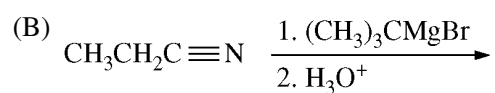
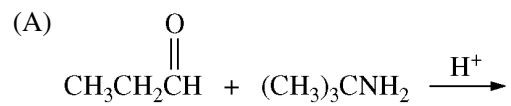
82. Which of the following is the major organic product of the reaction shown above?



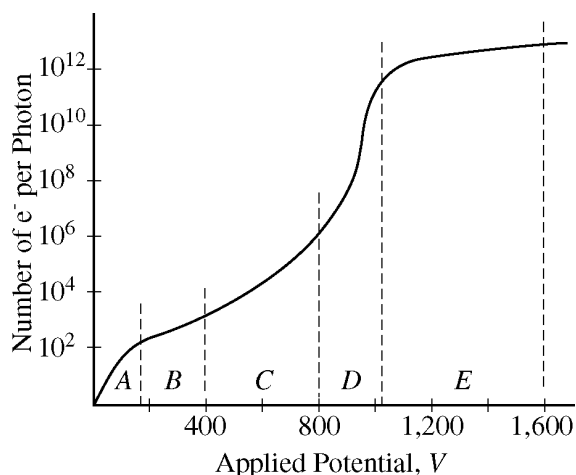
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83. Which of the following procedures gives the compound shown above?

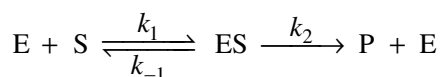


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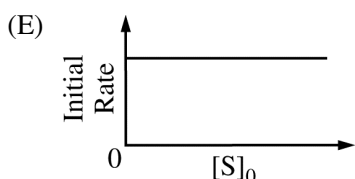
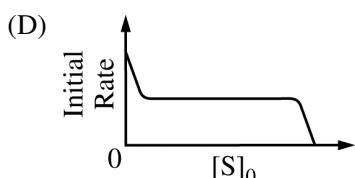
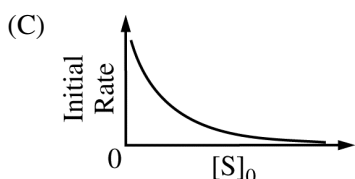
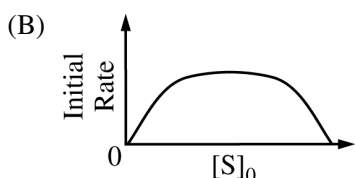
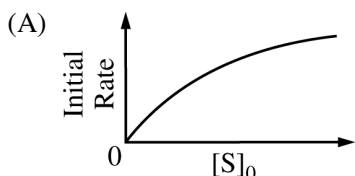
84. Ionizing radiation can be detected using gas-filled tubes in which released electrons migrate to a collector electrode, producing a pulse. On the figure shown above, which region would give the largest detector response per incident photon?
- (A) *A*
 (B) *B*
 (C) *C*
 (D) *D*
 (E) *E*
85. Which of the following is required for both paramagnetism and ferromagnetism?
- (A) Strong oxidizing conditions
 (B) Low-spin electron configuration
 (C) Metallic physical properties
 (D) Superexchange
 (E) Unpaired electrons
86. Redox enzyme catalysis involves the cyclic oxidation and reduction of metal ions that have at least two stable positive oxidation states. Which of the following groups of metals could be found at the active site of redox enzymes?
- (A) Cu, Fe, Co
 (B) Zn, Ca, Ga
 (C) Sr, Ga, Mg
 (D) Na, Ba, Al
 (E) Mg, Li, K
87. The solid-state structures of the principal allotropes of elemental boron are made up of which of the following structural units?
- (A) B_{12} icosahedra
 (B) B_8 cubes
 (C) B_6 octahedra
 (D) B_4 tetrahedra
 (E) Chains of B atoms
88. All proteins absorb electromagnetic radiation of wavelength around 190 nm, which corresponds to a $\pi \rightarrow \pi^*$ excitation in the protein molecule. In which region of the spectrum is this wavelength found?
- (A) X-ray
 (B) Ultraviolet
 (C) Visible
 (D) Infrared
 (E) Microwave

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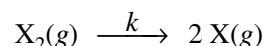
$$k = Ae^{-E_a/RT}$$

89. The mechanism shown above has been proposed for the enzyme-catalyzed hydrolysis of certain biochemical compounds (substrates), where ES is an enzyme-substrate complex. Given a fixed amount of enzyme, E, which of the following could be the plot of the initial rate of the production of product, P, when using varying initial concentrations of substrate, $[S]_0$?



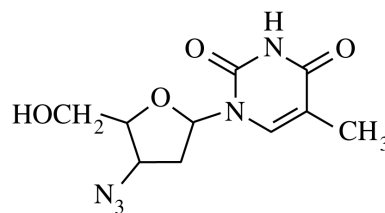
90. The rate constant of a bimolecular gas phase reaction is found to follow the Arrhenius equation shown above. Which of the following will result in a smaller rate constant?

- (A) Reducing activation energy
- (B) Reducing temperature
- (C) Reducing pressure
- (D) Reducing concentrations of reactants
- (E) Increasing molecular speeds



91. If the dissociation of X_2 proceeds by the elementary process shown above, the rate of change in $[X]$ with respect to time is given by

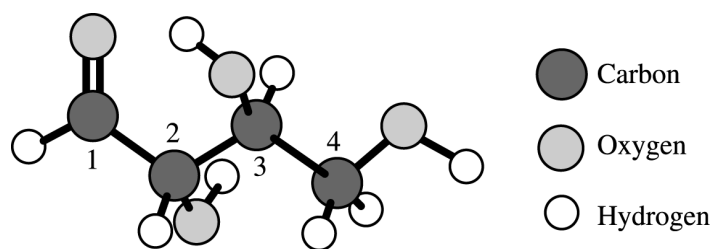
- (A) $\frac{d[X]}{dt} = \frac{k[X]}{[X_2]}$
- (B) $\frac{d[X]}{dt} = 2k[X_2]$
- (C) $\frac{d[X]}{dt} = k$
- (D) $\frac{d[X]}{dt} = k[X_2]^{1/2}$
- (E) $\frac{d[X]}{dt} = k[X_2]^2$



92. The compound shown above is AZT, a drug used in the treatment of acquired immune deficiency syndrome (AIDS). What is the total number of stereoisomers for this compound?

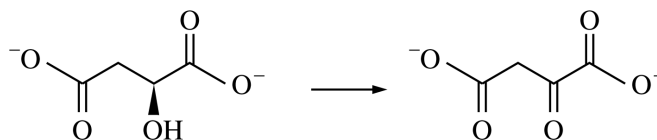
- (A) 2
- (B) 4
- (C) 6
- (D) 8
- (E) 10

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93. What is the stereochemistry of the carbohydrate structure shown above?

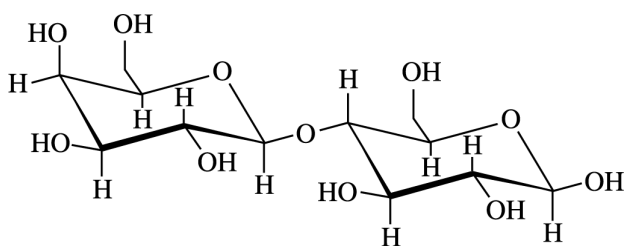
- (A) $2R, 3R$
- (B) $2R, 3S$
- (C) $2S, 3R$
- (D) $2S, 3S$
- (E) Meso



94. The enzyme-catalyzed transformation above, which occurs in the citric acid cycle (tricarboxylic acid or Krebs cycle), is best described as belonging to which of the following categories of reactions?

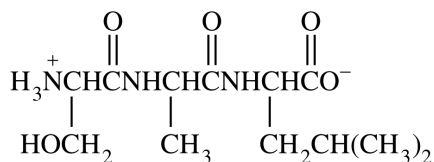
- (A) Oxidation
- (B) Reduction
- (C) Nucleophilic alkyl substitution
- (D) Aldol condensation
- (E) Hydrolysis

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95. Which of the following is NOT true about the disaccharide lactose shown above?

- (A) Lactose is a reducing sugar.
- (B) Lactose undergoes mutarotation.
- (C) Lactose is optically active.
- (D) Lactose can be hydrolyzed to monosaccharides with $\text{H}_2\text{O}/\text{H}_2\text{SO}_4$.
- (E) Lactose has a 1,1'- α - glycosidic linkage.



96. The compound shown above is a

- (A) triglyceride
- (B) trinucleotide
- (C) tripeptide
- (D) trisaccharide
- (E) triterpene

AAK ALLLG AGLLGGL
I II III

97. A peptide digest yields the three polypeptides listed above. The three peptides are separated using capillary electrophoresis at a pH (above 3) at which each peptide has the same total positive charge. Which of the following indicates the order, from first to last, that the peptides will reach the detector? (A = alanine; L = leucine; G = glycine; K = lysine).

- (A) I, II, III
- (B) I, III, II
- (C) II, I, III
- (D) II, III, I
- (E) III, II, I

98. In fluorescence spectroscopy, the quantum yield (Φ_f) is best defined as the

- (A) rate of fluorescence emission
- (B) number of photons emitted
- (C) number of photons emitted, divided by the number of photons absorbed
- (D) number of excitation photons impinging on the sample, divided by the number of photons absorbed
- (E) fraction of excited molecules produced by direct excitation

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99. When ferric oxide, Fe_2O_3 , is dissolved in 6 M HNO_3 , which iron-containing species predominates in solution?

- (A) FeO_2^-
- (B) $\text{Fe}(\text{OH})_4^-$
- (C) $\text{Fe}(\text{OH})_3$
- (D) $\text{Fe}(\text{H}_2\text{O})_6^{2+}$
- (E) $\text{Fe}(\text{H}_2\text{O})_6^{3+}$

100. Of the following ionic substances, which has the greatest lattice enthalpy?

- (A) MgO
- (B) MgS
- (C) NaF
- (D) NaCl
- (E) NaBr

101. Which of the following reactions is best classified as an oxidative addition?

- (A) $[\text{Cr}(\text{CO})_6] + \text{Br}^- \rightarrow [\text{Cr}(\text{CO})_5\text{Br}]^- + \text{CO}$
- (B) $[\text{PtH}(\text{CH}_3)\{\text{P}(\text{C}_6\text{H}_5)_3\}_2] + \text{P}(\text{C}_6\text{H}_5)_3 \rightarrow [\text{Pt}\{\text{P}(\text{C}_6\text{H}_5)_3\}_3] + \text{CH}_4$
- (C) $[\text{Pt}(\text{NH}_3)\text{Cl}_3]^- + \text{NH}_3 \rightarrow [\text{Pt}(\text{NH}_3)_2\text{Cl}_2] + \text{Cl}^-$
- (D) $[\text{Pt}\{\text{P}(\text{C}_2\text{H}_5)_3\}_2\text{HCl}] + \text{HCl} \rightarrow [\text{Pt}\{\text{P}(\text{C}_2\text{H}_5)_3\}_2(\text{H})_2\text{Cl}_2]$
- (E) $[\text{MnH}(\text{CO})_5] + \text{CF}_2=\text{CF}_2 \rightarrow [\text{Mn}(\text{CF}_2\text{CF}_2\text{H})(\text{CO})_5]$

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102. Of the following colligative properties, which is most practical for determining the extent of protein aggregation?

- (A) Osmotic pressure
- (B) Freezing point depression
- (C) Boiling point elevation
- (D) Solvent vapor pressure lowering
- (E) Solute vapor pressure

$$\psi_1 = 2s + 2p_x + 2p_y + 2p_z$$

$$\psi_2 = 2s + 2p_x - 2p_y - 2p_z$$

$$\psi_3 = 2s - 2p_x + 2p_y - 2p_z$$

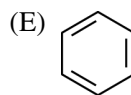
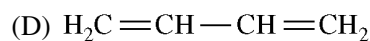
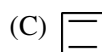
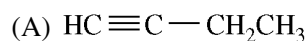
$$\psi_4 = 2s - 2p_x - 2p_y - 2p_z$$

103. A set of hybrid sp^3 orbitals for a carbon atom is given above. Which of the following is NOT true about the orbitals?

- (A) The orbitals are degenerate.
- (B) The set of orbitals has a tetrahedral geometry.
- (C) These orbitals are constructed from a linear combination of atomic orbitals.
- (D) The four electrons in these orbitals can form σ bonds with other atoms.
- (E) Each hybrid orbital may hold four electrons.

$$\begin{vmatrix} \alpha-E & \beta & 0 & 0 \\ \beta & \alpha-E & \beta & 0 \\ 0 & \beta & \alpha-E & \beta \\ 0 & 0 & \beta & \alpha-E \end{vmatrix} = 0$$

104. According to Hückel molecular orbital theory, the secular equation above can be used to find possible energy levels of the π -electrons in

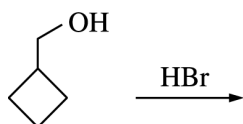


105. Which of the following is(are) characteristic of mass spectrometry?

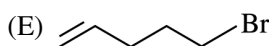
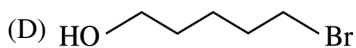
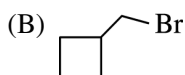
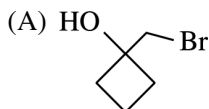
- I. Analyte molecules are converted to gaseous ions.
- II. The ions are separated according to their mass-to-charge ratio.
- III. In addition to compound identification, mass spectra can be utilized to determine precise isotopic masses and isotopic ratios.

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

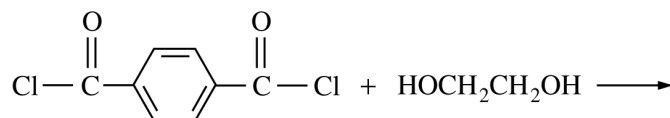
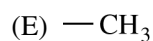
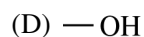
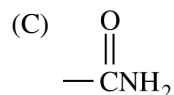
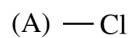
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106. Which of the following is the major rearrangement product of the reaction shown above?



107. Which of the following substituents is NOT an ortho, para director in an electrophilic aromatic substitution reaction?

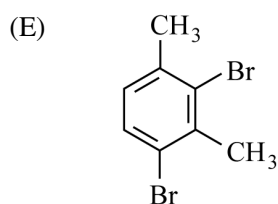
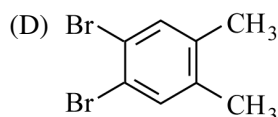
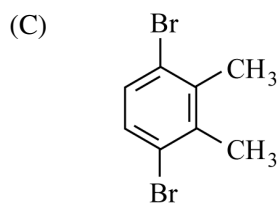
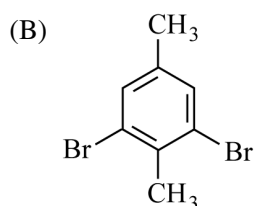
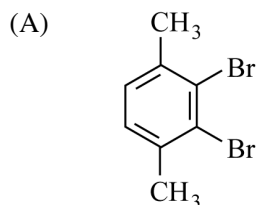


108. The reaction of terephthaloyl chloride with ethylene glycol, shown above, forms a

- (A) polyamide
- (B) polyester
- (C) polyether
- (D) polycarbonate
- (E) polyurethane

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109. The proton NMR spectrum of an aromatic compound, $C_8H_8Br_2$, includes two methyl singlets. Its proton-decoupled ^{13}C NMR spectrum displays a total of six peaks. Of the following, which structure best fits these data?



110. The fact that the infrared absorption frequency of deuterium chloride (DCl) is shifted from that of hydrogen chloride (HCl) is due to the differences in their

- (A) electron distribution
- (B) dipole moment
- (C) force constant
- (D) polarizability
- (E) reduced mass

111. In the vibrational-rotational spectrum of a diatomic molecule, the R-branch of the spectrum is the result of which of the following transitions?

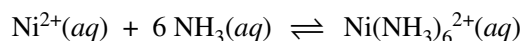
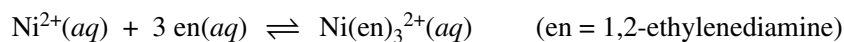
- (A) $\Delta J = 0$; $\Delta v = 0$
- (B) $\Delta J = 1$; $\Delta v = 0$
- (C) $\Delta J = 2$; $\Delta v = 0$
- (D) $\Delta J = 1$; $\Delta v = 1$
- (E) $\Delta J = 2$; $\Delta v = 1$

112. When an activated complex is formed from two reactant molecules in the gas phase, it is usually assumed that the entropy has been lowered; that is, ΔS^\ddagger is less than zero. This assumption is based on which of the following?

- (A) ΔU^\ddagger is positive.
- (B) ΔH^\ddagger is positive.
- (C) The preexponential factor A in the Arrhenius equation is always positive.
- (D) The activated complex is ill defined and transitory.
- (E) Forming the activated complex involves conversion of translational and rotational degrees of freedom into vibrational degrees of freedom.

GO ON TO THE NEXT PAGE.

113. A student performs five titrations and obtains a mean result of 0.110 M, with a standard deviation of 0.001 M. If the actual concentration of the titrated solution is 0.100 M, which of the following is true about the titration results?
- (A) Accurate but not precise
(B) Precise but not accurate
(C) Both accurate and precise
(D) Neither accurate nor precise
(E) There are insufficient data to determine the accuracy and precision of the results.
114. Which of the following statements about the lanthanide elements is NOT true?
- (A) The most common oxidation state for the lanthanide elements is +3.
(B) Lanthanide complexes often have high coordination numbers (> 6).
(C) All of the lanthanide elements react with aqueous acid to liberate hydrogen.
(D) The lanthanides form stable complexes with chelating oxygen ligands.
(E) The atomic radii of the lanthanide elements increase across the period from La to Lu.
-



115. The equilibrium constant for the formation of $\text{Ni}(\text{en})_3^{2+}$, shown above, is 10^{10} -fold greater than the equilibrium constant for the formation of $\text{Ni}(\text{NH}_3)_6^{2+}$. The primary explanation for this large difference is termed the
- (A) Jahn-Teller effect
(B) Tyndall effect
(C) ammonia effect
(D) crystal field effect
(E) chelate effect

GO ON TO THE NEXT PAGE.

116. Which of the following is a true statement about optical isomerism of complexes containing achiral ligands?
- (A) Square planar complexes can display optical isomerism only if all four ligands are identical.
- (B) Tetrahedral complexes never display optical isomerism.
- (C) Linear complexes can display optical isomerism when both ligands are different.
- (D) Octahedral complexes of monodentate ligands can display optical isomerism only when they have at least three different ligands.
- (E) Trigonal bipyramidal complexes display optical isomerism when their axial ligands differ from their equatorial ligands.

117. An organic compound has a distribution coefficient, K_p , of 2.00 between an ether and water. If 10.0 g of the compound is dissolved in 100 mL of water that is then extracted twice with 100 mL portions of the ether, what fraction of the compound remains in the water? $\left(K_p = \frac{C_{ether}}{C_{water}} \right)$

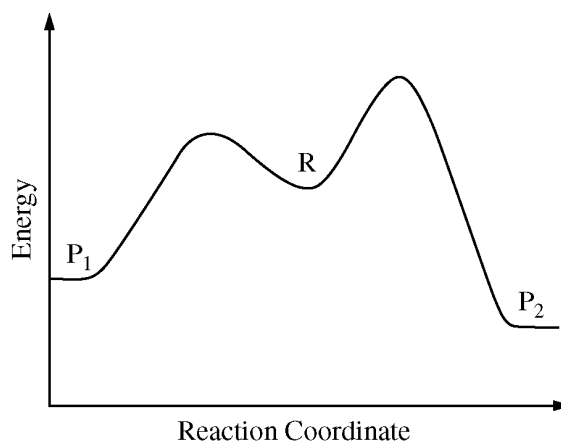
- (A) 0.111
 (B) 0.200
 (C) 0.250
 (D) 0.500
 (E) 0.889

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

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

119. When the Heisenberg uncertainty principle is applied to a quantum mechanical particle in the lowest energy level of a one-dimensional box, which of the following is true?

- (A) Momentum is known exactly, but no information about position can be known.
- (B) Position is known exactly, but no information about momentum can be known.
- (C) No information about either position or momentum can be known.
- (D) Both position and momentum can be known exactly.
- (E) Neither position nor momentum can be known exactly.



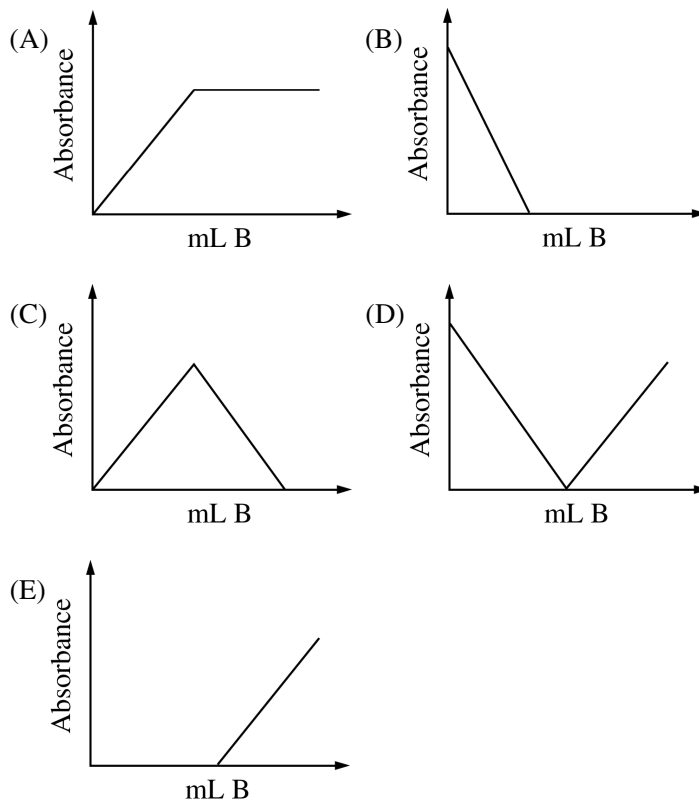
120. A reactant, R, can produce either of two products, P_1 or P_2 , with competing pathways, as illustrated in the reaction profile shown above. If the reaction is carried out at low temperature, which of the following best indicates the preferred product and the type of control?

	<u>Preferred Product</u>	<u>Control</u>
(A)	P_1	Kinetic
(B)	P_1	Thermodynamic
(C)	P_2	Kinetic
(D)	P_2	Thermodynamic
(E)	R	Thermodynamic

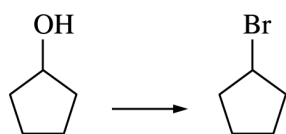
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<u>Substance</u>	<u>Wavelengths Absorbed (nm)</u>
A	400–600, 700–800
B	< 400, 500–700
C	< 400

121. For the titration reaction $A + B \rightarrow C$, where A = analyte, B = titrant, and C = product, the end point is to be detected spectrophotometrically at 550 nm, based on the absorbance information shown above. The shape of the titration curve at 550 nm would most closely resemble which of the following?

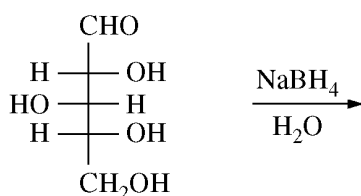


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122. Which of the following reagents can be used to convert cyclopentanol to bromocyclopentane, as shown above?

- (A) NaBr
- (B) PBr₃
- (C) Br₂, CCl₄
- (D) *N*-bromosuccinimide (NBS), *hν*
- (E) Br₂, H₂O

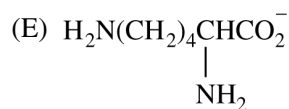
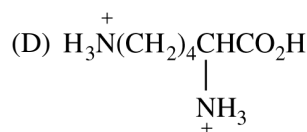
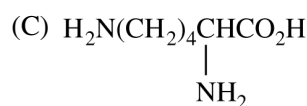
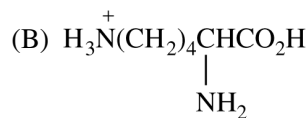
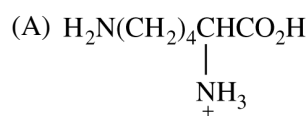


D-xylose

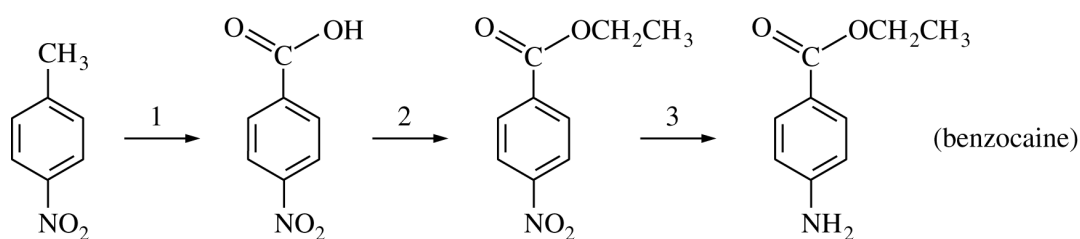
123. Reduction of D-xylose with NaBH₄ yields a product that is a

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

124. Which of the following structures represents the amino acid lysine at pH 1 ?



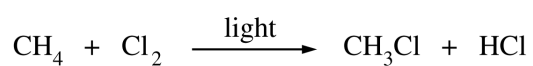
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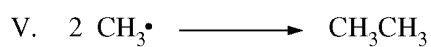
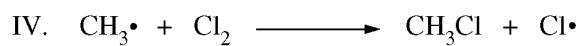
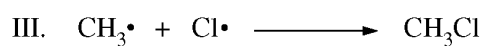
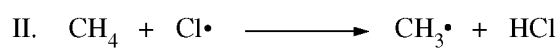
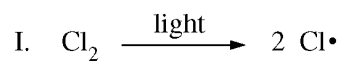
125. The reaction sequence shown above can be used to prepare benzocaine from 4-nitrotoluene. Which of the following reaction sequences would accomplish this synthesis?

- (A) 1. $\text{Na}_2\text{Cr}_2\text{O}_7, \text{H}_2\text{SO}_4$
 2. $\text{CH}_3\text{CH}_2\text{OH}, \text{H}^+$
 3. Sn, HCl followed by NaOH
- (B) 1. $\text{NaBH}_4, \text{CH}_3\text{OH}$
 2. $\text{CH}_3\text{CH}_2\text{OH}, \text{H}^+$
 3. Sn, HCl followed by NaOH
- (C) 1. $\text{H}_2\text{O}, \text{HCl}$
 2. $\text{CH}_3\text{CH}_2\text{ONa}$
 3. Sn, HCl followed by NaOH
- (D) 1. $\text{Na}_2\text{Cr}_2\text{O}_7, \text{H}_2\text{SO}_4$
 2. $\text{CH}_3\text{CH}_2\text{ONa}$
 3. $\text{NaBH}_4, \text{CH}_3\text{OH}$
- (E) 1. $\text{Na}_2\text{Cr}_2\text{O}_7, \text{H}_2\text{SO}_4$
 2. $\text{CH}_3\text{CH}_2\text{OH}, \text{H}^+$
 3. $\text{H}_2\text{O}, \text{HCl}$

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126. Which two of the following are the propagation steps in the free-radical chlorination of methane shown above?

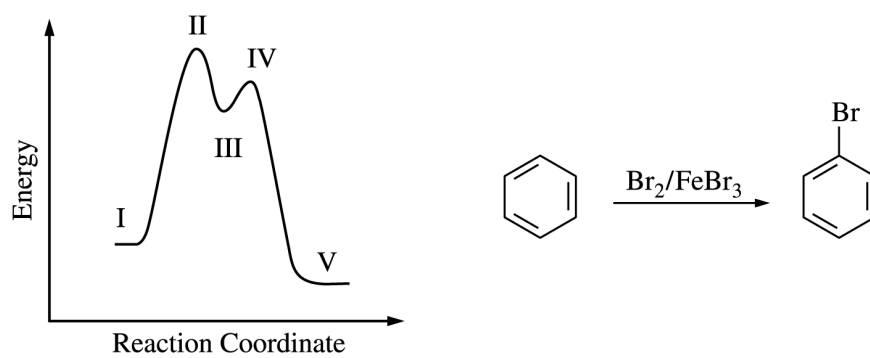


- (A) I and II
(B) II and III
(C) II and IV
(D) III and IV
(E) IV and V

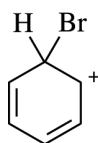
127. What is the limiting high-temperature molar heat capacity at constant volume (C_V) of a gas-phase diatomic molecule?

- (A) $\frac{3}{2}R$
(B) $2R$
(C) $\frac{5}{2}R$
(D) $3R$
(E) $\frac{7}{2}R$

GO ON TO THE NEXT PAGE.



128. The reaction energy diagram for the electrophilic bromination of benzene with Br_2 and FeBr_3 is shown above. Which position on the diagram corresponds to the species shown below?



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

GO ON TO THE NEXT PAGE.

129. Of the following atoms, which has the lowest electron affinity?

- (A) F
- (B) Si
- (C) O
- (D) Ca
- (E) Br

130. Which of the following is a primary standard for use in standardizing bases?

- (A) Ammonium hydroxide
- (B) Sulfuric acid
- (C) Acetic acid
- (D) Potassium hydrogen phthalate
- (E) Silver nitrate

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	1	2	0
⓪	⓪	⓪	⓪	●
①	①	●	①	①
●	②	②	●	②
③	③	③	③	③
④	④	④	④	④
⑤	⑤	⑤	⑤	⑤
⑥	⑥	⑥	⑥	⑥
⑦	●	⑦	⑦	⑦
⑧	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 GR0727

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

- | | |
|------------------|-------------|
| (A) ● | (C) (D) (E) |
| (A) B | (C) (D) (E) |
| (A) ✓ | (C) (D) (E) |
| (A) ● | (C) (D) (E) |
| (A) F | (C) (D) (E) |

CORRECT ANSWER
PROPERLY MARKED

IMPROPER MARKS

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



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Princeton, New Jersey 08541

Worksheet for the GRE Chemistry Test, Form GR0727
Answer Key and Percentages* of Test Takers Answering Each Question Correctly

QUESTION		P+	RESPONSE	
Number	Answer		C	I
1	D	73		
2	E	43		
3	C	71		
4	D	39		
5	A	80		
6	D	42		
7	C	60		
8	B	38		
9	C	46		
10	D	61		
11	B	85		
12	B	92		
13	E	45		
14	D	82		
15	E	25		
16	E	70		
17	A	98		
18	E	87		
19	D	67		
20	C	38		
21	E	50		
22	B	72		
23	A	42		
24	D	13		
25	C	95		
26	B	45		
27	E	24		
28	D	77		
29	E	80		
30	B	93		
31	C	53		
32	D	39		
33	A	38		
34	E	51		
35	C	38		
36	D	34		
37	A	33		
38	A	65		
39	B	49		
40	B	57		
41	E	90		
42	A	63		
43	D	52		
44	B	71		
45	B	40		

QUESTION		P+	RESPONSE	
Number	Answer		C	I
46	A	66		
47	E	46		
48	A	71		
49	E	31		
50	D	65		
51	E	31		
52	A	61		
53	E	37		
54	E	52		
55	C	63		
56	A	56		
57	D	54		
58	C	60		
59	A	53		
60	E	63		
61	C	61		
62	E	69		
63	D	40		
64	A	81		
65	D	89		
66	A	83		
67	D	48		
68	E	75		
69	E	12		
70	C	64		
71	D	37		
72	B	66		
73	A	33		
74	B	58		
75	C	85		
76	A	54		
77	E	62		
78	D	50		
79	B	64		
80	A	58		
81	B	72		
82	A	65		
83	A	54		
84	E	42		
85	E	71		
86	A	87		
87	A	17		
88	B	71		
89	A	71		
90	B	69		

QUESTION		P+	RESPONSE	
Number	Answer		C	I
91	B	34		
92	D	44		
93	D	51		
94	A	66		
95	E	49		
96	C	77		
97	A	60		
98	C	48		
99	E	33		
100	A	25		
101	D	19		
102	A	42		
103	E	65		
104	D	22		
105	E	69		
106	C	44		
107	C	44		
108	B	73		
109	B	62		
110	E	53		
111	D	27		
112	E	37		
113	B	76		
114	E	57		
115	E	49		
116	D	35		
117	A	38		
118	E	74		
119	E	45		
120	A	53		
121	D	33		
122	B	37		
123	E	31		
124	D	75		
125	A	55		
126	C	71		
127	E	10		
128	C	58		
129	D	88		
130	D	51		

Total Correct (C) _____

Total Incorrect (I) _____

Total Score (C-1/4) _____

Scaled Score (SS) _____

* The numbers in the P+ column are indicative of the percentages of U.S. GRE Chemistry examinees who would answer each question correctly.