2009 U. S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Olympiad Examinations Task Force

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DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records his or her responses. All answers are to be marked on that sheet, not written in the booklet. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet at the end of the examination. Local Sections may use an answer sheet of their own choice.

The full examination consists of 60 multiple-choice questions representing a fairly wide range of difficulty. Students should be permitted to use non-programmable calculators. A periodic table and other useful information are provided on page two of this exam booklet for student reference.

Suggested Time: 60 questions—110 minutes

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

This is a multiple-choice examination with four choices for each question. There is only *one* correct or best answer to each question. When you select your choice, blacken the corresponding space on the answer sheet with your pencil. Make a heavy full mark, but no stray marks. If you decide to change your answer, be certain to erase your original answer completely.

Not valid for use as an ACS Olympiad Local Section Exam after March 31, 2009. STOCK CODE OL09

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ABBREVIATIONS AND SYMBOLS					
amount of substance	n	Faraday constant	F	molar	M
ampere	A	free energy	G	molar mass	M
atmosphere	atm	frequency	ν	mole	mol
atomic mass unit	u	gas constant	R	Planck's constant	h
atomic molar mass	A	gram	g	pressure	P
Avogadro constant	N_A	hour	h	rate constant	k
Celsius temperature	°C	joule	J	reaction quotient	Q
centi– prefix	c	kelvin	K	second	s
coulomb	C	kilo– prefix	k	speed of light	c
electromotive force	E	liter	L	temperature, K	T
energy of activation	E_a	measure of pressure	mmHg	time	t
enthalpy	H	milli– prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K				

CONSTANTS
$R = 8.314\ \text{J·mol}^{-1}\text{·K}^{-1}$
$R = 0.0821\ \text{L·atm·mol}^{-1}\text{·K}^{-1}$
$1\ F = 96{,}500\ \text{C·mol}^{-1}$
$1\ F = 96{,}500\ \text{J·V}^{-1}\text{·mol}^{-1}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.626 \times 10^{-34}\ \text{J·s}$
$c = 2.998 \times 10^{8}\ \text{m·s}^{-1}$
0 °C = 273.15 K

EQUATIONS

$$E = E^{\circ} - \frac{RT}{nF}\ln Q \qquad \ln K = \left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T}\right) + \text{constant} \qquad \ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 **H** 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	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** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (269)	111 **Rg** (272)	112 **Uub** (277)		114 **Uuq** (2??)				

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

DIRECTIONS

- When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a soft, #2 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **will not be counted**.
- Your score is based solely on the number of questions you answer correctly. **It is to your advantage to answer every question.**

1. Which salt is colorless?

(A) $KMnO_4$ **(B)** $BaSO_4$

(C) Na_2CrO_4 **(D)** $CoCl_2$

2. Which 0.10 M aqueous solution exhibits the lowest electrical conductivity?

(A) NH_4Cl **(B)** $CuBr_2$

(C) Na_2CO_3 **(D)** C_2H_5OH

3. Which element is a liquid at 25°C and 1 atm?

(A) fluorine **(B)** chlorine

(C) bromine **(D)** iodine

4. Mixing which combination produces a gaseous product?

(A) solid ammonium nitrate and solid calcium hydroxide

(B) copper metal and 0.10 M hydrochloric acid

(C) solutions of barium hydroxide and 0.10 M sulfuric acid

(D) solutions of aluminum nitrate and sodium chloride

5. Which technique can be used to determine the number of components in a plant pigment?

(A) calorimetry **(B)** chromatography

(C) colorimetry **(D)** gravimetry

6. In the determination of the molar mass of a solid acid by titrating it with a standardized base, which procedural error will yield a molar mass that is smaller than the actual value?

(A) adding the standardized base to a buret containing drops of water

(B) dissolving the weighed solid acid in twice the recommended volume of water

(C) using half as many drops of indicator as suggested

(D) weighing out half of the recommended mass of solid acid

7. The mass of one atom of an element is 1.71×10^{-22} g. What is the atomic mass of this element in $g\cdot mol^{-1}$?

(A) 101 **(B)** 103 **(C)** 105 **(D)** 107

8. What is the percent by mass of nitrogen in ammonium carbonate, $(NH_4)_2CO_3$?

(A) 14.53% **(B)** 27.83%

(C) 29.16% **(D)** 33.34%

9. How many moles of water will be produced from the complete combustion of 4.4 g of C_3H_8?

(A) 0.10 **(B)** 0.25 **(C)** 0.40 **(D)** 0.80

10. A 10.0 g sample of an oxide of copper forms metallic copper and 1.26 g of water when heated in a stream of hydrogen. What is the mass percent of copper in this oxide?

(A) 11.2% **(B)** 66.6% **(C)** 79.9% **(D)** 88.8%

Molar Mass / $g\cdot mol^{-1}$	
$Ba(OH)_2\cdot8H_2O$	315

11. A 49.9 g sample of barium hydroxide octahydrate, $Ba(OH)_2\cdot8H_2O$, is dissolved in water and the solution is diluted to give a final volume of 2.50 L. What is the concentration of the hydroxide ion in this solution?

(A) 0.0634 M **(B)** 0.127 M

(C) 0.190 M **(D)** 0.634 M

12. What volume (in mL) of 0.0500 M phosphoric acid is needed to titrate completely 25.0 mL of 0.150 M barium hydroxide solution to a phenolphthalein end point?

$$3Ba(OH)_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$$

(A) 50.0 **(B)** 75.0 **(C)** 100. **(D)** 150.

13. A sample of gas at 273 K has a pressure of P_1 and a volume of V_1. When the pressure is changed to P_2, what is the volume V_2? (Assume the temperature remains constant.)

(A) $\frac{P_1P_2}{V_1}$ **(B)** $\frac{P_1V_1}{P_2}$

(C) $\frac{P_2V_1}{P_1}$ **(D)** $\frac{P_2}{P_1V_1}$

14. How do the number of molecules, n, in 1.0 L of each of the following gases; CH_4, N_2, CO_2, compare at 1 atm and 25 °C?

(A) $n_{CH_4} < n_{CO_2} < n_{N_2}$ **(B)** $n_{N_2} < n_{CO_2} < n_{CH_4}$

(C) $n_{CO_2} < n_{CH_4} < n_{N_2}$ **(D)** $n_{CH_4} = n_{CO_2} = n_{N_2}$

15. Solid sodium acetate, $NaC_2H_3O_2$, is what type of solid?

(A) ionic **(B)** metallic

(C) molecular **(D)** network covalent

16. Which substance has the highest vapor pressure at 25°C?

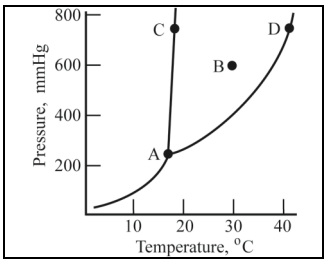
(A) methanol, CH_3OH

(B) ethanol, CH_3CH_2OH

(C) 1-propanol, $CH_3CH_2CH_2OH$

(D) 1-butanol, $CH_3CH_2CH_2CH_2OH$

17. Which point on the phase diagram represents the normal boiling point?



(A) point A **(B)** point B

(C) point C **(D)** point D

18. What types of intermolecular forces are exerted by CH_3Cl molecules in the liquid phase?

I.	dipole-dipole forces
II.	hydrogen bonding
III.	London dispersion forces

(A) I only **(B)** II only

(C) I and III only **(D)** II and III only

19. A 22.0 g piece of metal is heated to 100.0°C and placed in 75.0 g H_2O at 25.0°C. If the final temperature of the metal and water is 27.8°C, what is the specific heat capacity of the metal in $J \cdot g^{-1} \cdot °C^{-1}$? (Assume no heat is lost/gained by the surroundings.)

	C_p / $J \cdot g^{-1} \cdot °C^{-1}$
H_2O	4.18

(A) 0.038 **(B)** 0.16 **(C)** 0.55 **(D)** 5.0

20. Which change(s) is(are) accompanied by an increase in entropy of the system?

I.	conversion of $O_2(g)$ to $O_3(g)$
II.	freezing of water
III.	sublimation of iodine

(A) I only **(B)** III only

(C) I and II only **(D)** II and III only

21. $NO(g) \rightarrow \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ ΔH_1°

$2NO(g) \rightarrow N_2O(g) + \frac{1}{2}O_2(g)$ ΔH_2°

Which relationship is correct?

(A) $\Delta H_1^\circ = \Delta H_2^\circ$

(B) ΔH_f° for $NO(g) = \Delta H_1^\circ$

(C) ΔH_f° for $N_2O(g) = \Delta H_2^\circ$

(D) ΔH_f° for $N_2O(g) = \Delta H_2^\circ - 2\Delta H_1^\circ$

22. When 2.74 g of Ba(s) reacts with $O_2(g)$ at 298 K and 1 atm to form BaO(s), 11,100 J of heat is released. What is ΔH_f° for BaO(s) in $kJ \cdot mol^{-1}$?

(A) 556 **(B)** 221 **(C)** –221 **(D)** –556

23. A reaction has $\Delta H^\circ > 0$ and $\Delta G^\circ > 0$ at 25°C. This reaction

(A) is at equilibrium at 25°C.

(B) could not be spontaneous under standard conditions at any temperature.

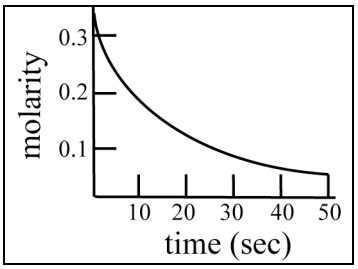
(C) could be spontaneous under standard conditions at temperatures above 25°C.

(D) could be spontaneous under standard conditions at temperatures below 25°C.

24. An ionic compound has a solubility of 1 $mol \cdot L^{-1}$ in water at 25 °C and its solubility increases as the temperature is raised. What are the signs of ΔH° and ΔS° for the dissolving process?

	ΔH°	ΔS°
(A)	+	+
(B)	+	–
(C)	–	+
(D)	–	–

25. For the reaction represented by the accompanying diagram, which reaction rate is the greatest?



(A) average rate **(B)** final rate

(C) initial rate **(D)** rate at 20 seconds

26. Which units are appropriate for a reaction rate?

(A) $mol \cdot L^{-1} \cdot s^{-1}$ **(B)** $mol \cdot L^{-1}$

(C) $mol \cdot L \cdot s^{-1}$ **(D)** $L \cdot mol^{-1} \cdot s^{-1}$

27. What is the rate equation for a reaction, A + B → products, based on the rate data?

$[A]_o$, mol·L^{-1}	$[B]_o$, mol·L^{-1}	Rate
0.15	0.10	x
0.30	0.20	4x
0.30	0.40	16x

(A) Rate = $k[A]^2$ **(B)** Rate = $k[B]^2$

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

28. The effect of temperature on the rates of chemical reactions is primarily a result of the

(A) size of the colliding molecules.

(B) orientation of the colliding molecules.

(C) enthalpies of the reactants and products.

(D) kinetic energies of the colliding molecules.

29. The value of the rate constant for a gas phase reaction can be changed by increasing the

(A) amount of product.

(B) pressure of the reactant.

(C) temperature of the reaction vessel.

(D) volume of the reaction vessel.

30. What is the half life of the irreversible first order reaction, A → B, if 75% of A is converted to B in 60 minutes?

(A) 30 minutes **(B)** 45 minutes

(C) 60 minutes **(D)** 80 minutes

31. What is the K_{eq} expression for the reaction, $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$?

(A) $K_{eq} = \dfrac{2[CO]}{[CO_2]}$ **(B)** $K_{eq} = \dfrac{2[C][CO]}{[CO_2]}$

(C) $K_{eq} = \dfrac{[CO]^2}{[CO_2]}$ **(D)** $K_{eq} = \dfrac{[C][CO]^2}{[CO_2]}$

32. The equilibrium system $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ has $K_p = 11$ and $\Delta H° = 57$ kJ·mol^{-1} at 25 °C. Which action will **not** cause a change in the position of the equilibrium?

(A) increasing the temperature

(B) adding $NO_2(g)$

(C) adding xenon gas to increase the pressure

(D) increasing the container volume

33. Which is not a conjugate acid/base pair?

(A) H_2CO_3 & CO_3^{2-} **(B)** HSO_4^- & SO_4^{2-}

(C) $H_2PO_4^-$ & HPO_4^{2-} **(D)** H_3O^+ & H_2O

34. What is the $[OH^-]$ in an aqueous solution which has a pH = 11.70?

(A) 7.1×10^{-2} M **(B)** 5.0×10^{-3} M

(C) 1.4×10^{-6} M **(D)** 2.0×10^{-12} M

35. Equal volumes of 0.25 M HNO_2 and 0.25 M HNO_3 are titrated separately with 0.25 M KOH. Which would be the same for both titrations?

(A) initial pH

(B) pH halfway to the equivalence point

(C) pH at the equivalence point

(D) pH when 5 mL excess KOH has been added

36. For which salt is the molar solubility, s, equal to 4×10^{-6} M?

(A) $AgC_2H_3O_2$ $K_{sp} = 2\times10^{-3}$

(B) TlBr $K_{sp} = 4\times10^{-6}$

(C) $MnCO_3$ $K_{sp} = 2\times10^{-11}$

(D) $Zn(OH)_2$ $K_{sp} = 3\times10^{-17}$

37. Which substance can act only as a reducing agent?

(A) I_2 **(B)** BrCl **(C)** NaBr **(D)** HIO_4

38. When the equation $Sn^{2+}(aq) + IO_3^-(aq) + H^+(aq) \rightarrow Sn^{4+}(aq) + I_2(aq) + H_2O(l)$ is balanced, what is the $Sn^{2+}(aq)$ / IO_3^- (aq) mole ratio?

(A) 1 / 1 **(B)** 2 / 1 **(C)** 1 / 2 **(D)** 5 / 2

39. Given the standard reduction potentials, which statement is correct?

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E° = 0.34$ V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	$E° = 0.00$ V
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	$E° = -0.73$ V

(A) Cr(s) will react with acid.

(B) Cu(s) will react with acid.

(C) $Cu^{2+}(aq)$ will react with acid.

(D) Cu(s) will react with $Cr^{3+}(aq)$.

40. Use the standard reduction potentials given to calculate the standard potential for the reaction;

$$Pb(s) + 2Ag^+(aq) \rightarrow Pb^{2+}(aq) + 2Ag(s)$$

$Ag^+(aq) + e^- \rightarrow Ag(s)$	$E^\circ = 0.80$ V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	$E^\circ = -0.13$ V

(A) 1.73 V **(B)** 0.93 V **(C)** 0.67V **(D)** 0.54 V

41. For the voltaic cell represented,

$$Ni(s)\left|Ni^{2+}(aq)\right\|Ag^+(aq)\left|Ag(s)\right.$$

which change will increase the cell potential?

(A) increasing the $[Ag^+]$ **(B)** increasing the $[Ni^{2+}]$

(C) adding Ni(s) **(D)** removing Ag(s)

42. The deposition of 1.0 g of which element from its molten chloride requires the shortest time at a current of 1 A?

(A) Na **(B)** Mg **(C)** Al **(D)** Ba

43. Which properties of electromagnetic radiation are inversely related?

(A) amplitude and frequency

(B) energy and wavelength

(C) energy and frequency

(D) wavelength and amplitude

44. Which electronic transition in a hydrogen atom releases the greatest amount of energy?

(A) $n = 3 \rightarrow n = 2$ **(B)** $n = 5 \rightarrow n = 3$

(C) $n = 6 \rightarrow n = 5$ **(D)** $n = 3 \rightarrow n = 6$

45. Which must represent an atom in an excited state?

(A) $1s^2 2s^2 2p^1$ **(B)** $1s^2 2s^2 2p^2$

(C) $1s^2 2s^2 2p^2 3s^1$ **(D)** $1s^2 2s^2 2p^5$

46. Which quantum numbers represent the orbitals being filled in the ground state for the elements Sc (21) to Zn (30)?

(A) $n = 3, l = 1$ **(B)** $n = 3, l = 2$

(C) $n = 4, l = 1$ **(D)** $n = 4, l = 2$

47. Which pair consists of species that are isoelectronic?

(A) Na^+, K^+ **(B)** Cl, Cl^-

(C) Fe^{2+}, Mn^{2+} **(D)** Ar, Ca^{2+}

48. In which series are the species listed in order of increasing size?

(A) N, O, F **(B)** Na, Mg, K

(C) Cr, Cr^{2+}, Cr^{3+} **(D)** Cl, Cl^-, S^{2-}

49. In which molecule does the chlorine have the most positive partial charge?

(A) HCl **(B)** BrCl **(C)** OCl_2 **(D)** SCl_2

50. Which molecule contains the shortest carbon-carbon bonds?

(A) C_2H_2 **(B)** C_2H_4 **(C)** C_3H_8 **(D)** C_6H_{12}

51. How many valence electrons are in one ion of thiosulfate, $S_2O_3^{2-}$?

(A) 26 **(B)** 28 **(C)** 30 **(D)** 32

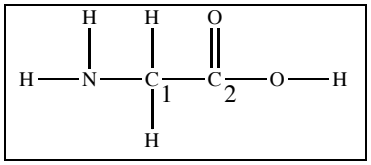
52. Which substance has the highest melting point?

(A) CO **(B)** CO_2 **(C)** SiO_2 **(D)** P_2O_5

53. Which species has exactly five pairs of electrons around the central atom?

(A) ClF_5 **(B)** SF_4 **(C)** SF_5^- **(D)** XeF_4

54. What are the hybridizations of the carbon atoms labeled C_1 and C_2, respectively, in glycine?



	C_1	C_2
(A)	sp^2	sp^2
(B)	sp^2	sp^3
(C)	sp^3	sp^2
(D)	sp^3	sp^3

55. The formula, H_3CCOCH_3, represents a(n)

(A) aldehyde. **(B)** ester.

(C) ether. **(D)** ketone.

56. Which suffix is used to designate a carbohydrate?

(A) –ase **(B)** –ate **(C)** –one **(D)** –ose

57. Which compound has the largest molar mass?

(A) hexane **(B)** 1-hexene

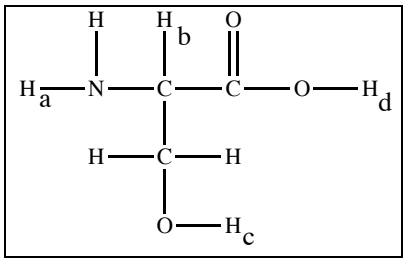
(C) 1-hexyne **(D)** benzene

58. Which functional group is not commonly found in proteins?

(A) alcohol **(B)** aldehyde

(C) amide **(D)** amine

59. Which hydrogen is the most acidic in the molecule shown?



(A) H_a **(B)** H_b **(C)** H_c **(D)** H_d

60. The gentle oxidation of ethanol, CH_3CH_2OH, produces

(A) ethanal, CH_3CHO.

(B) ethanoic acid, CH_3CO_2H.

(C) carbon monoxide, CO.

(D) carbon dioxide, CO_2.

END OF TEST

Olympiad 2009 Local Section

KEY

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

Number	Answer
31.	C
32.	C
33.	A
34.	B
35.	D
36.	C
37.	C
38.	D
39.	A
40.	B
41.	A
42.	D
43.	B
44.	A
45.	C
46.	B
47.	D
48.	D
49.	C
50.	A
51.	D
52.	C
53.	B
54.	C
55.	D
56.	D
57.	A
58.	B
59.	D
60.	A