2006 U. S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

Arden P. Zipp, State University of New York, Cortland, Chair

Sherry Berman-Robinson, Consolidated High School, IL

William Bond, Snohomish High School, WA

Peter E. Demmin (retired), Amherst Central High School, NY

Marian Dewane, Centennial High School, ID

Kimberly Gardner, US Air Force Academy, CO

Preston Hayes, Glenbrook South High School, IL

David W. Hostage, Taft School, CT

Adele Mouakad, St. John's School, PR

Jane Nagurney, Scranton Preparatory School, PA

Ronald O. Ragsdale, University of Utah, UT

Todd Trout, Lancaster Country Day School, PA

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 28, 2006. STOCK CODE OL06

Distributed by the ACS DivCHED Examinations Institute, University of Wisconsin - Milwaukee, Milwaukee, WI.

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

CONS

$R = 8.314$ J·m

$R = 0.0821$ L·atm·mo

1 F = 96,500 C·mol

1 F = 96,500 J·V^{-1}·mol^{-1}

$N_A = 6.022 \times 10^{23}$ mol^{-1}

$h = 6.626 \times 10^{-34}$ J·s

$c = 2.998 \times 10^{8}$ m·s^{-1}

0 °C = 273.15 K

1 atm = 760 mmHg

note: the notation m·s^{-1} should be read meters per second

EQUATIONS

$$E = E^{o} - \frac{RT}{nF}\ln Q$$

$$\ln K = \left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T}\right) + \text{constant}$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

PERIODIC TABLE OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	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											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 **Uun** (269)	111 **Uuu** (272)	112 **Uub** (277)		114 **Uuq** (2??)		116 **Uuh** (2??)		118 **Uuo** (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 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **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 gas should not be collected over water because of its high solubility in water?

(A) H_2 **(B)** CO **(C)** CH_4 **(D)** HCl

2. A student wishes to measure 17.3 mL of a standard solution. This can be done best using which container?

(A) 25 mL beaker **(B)** 25 mL volumetric pipet
(C) 25 mL buret **(D)** 25 mL volumetric flask

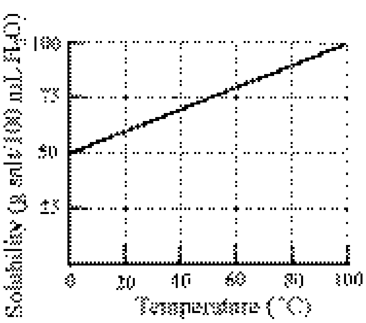
3. In a familiar classroom demonstration, concentrated H_2SO_4 is added to a beaker containing sucrose ($C_{12}H_{22}O_{11}$), to produce a column of carbon. In this reaction the H_2SO_4 is acting primarily as a

(A) complexing agent. **(B)** dehydrating agent.
(C) oxidizing agent. **(D)** precipitating agent.

4. Aqua regia, the reagent that can be used to dissolve gold, is a 3:1 mixture of which acids?

(A) hydrochloric and sulfuric acids
(B) hydrofluoric and nitric acids
(C) hydrochloric and nitric acids
(D) perchloric and sulfuric acids

5. The solubility of a solid in H_2O at different temperatures is indicated in the accompanying diagram. What mass of the solid will crystallize when 40. mL of a solution that is saturated at 80 ˚C is cooled to 20 ˚C?



(A) 12 g **(B)** 24 g **(C)** 30 g **(D)** 36 g

6. A student is asked to determine the degree of hydration of a salt by finding the mass of a clean dried crucible and lid followed by the mass of the crucible and lid containing a sample of the salt. The crucible, lid and salt are heated in a Bunsen burner flame, cooled, and weighed. If the crucible, lid and salt are heated only once instead of the recommended three times, what will be the effect on the degree of hydration compared with the actual value?

(A) too high **(B)** too low
(C) unaffected **(D)** impossible to predict

7. Which is the net ionic equation for the reaction when 0.10 M solutions of silver nitrate and sodium sulfide are mixed?

(A) $Ag^+(aq) + S^-(aq) \rightarrow AgS(s)$
(B) $Ag^{2+}(aq) + S^{2-}(aq) \rightarrow AgS(s)$
(C) $Ag^{2+}(aq) + S^-(aq) \rightarrow AgS_2(s)$
(D) $Ag^+(aq) + S^{2-}(aq) \rightarrow Ag_2S(s)$

8. Magnetite, which has the formula Fe_3O_4, is comprised of iron(II) oxide and iron(III) oxide. What is the ratio of iron(II) ions to iron(III) ions in magnetite?

(A) 1:1 **(B)** 1:2 **(C)** 2:3 **(D)** 3:2

9. $$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$
What is the total mass, in grams, of products when 2.20 g of propane is burned in excess oxygen?

(A) 2.20 **(B)** 3.60 **(C)** 6.60 **(D)** 10.2

10. What volume, in mL, of concentrated sulfuric acid (18.0 M H_2SO_4) is needed to prepare 2.50 L of a 1.00 M solution?

(A) 7.20 **(B)** 14.4 **(C)** 69.4 **(D)** 139

11. The bromide impurity in a 2.00 g sample of a metal nitrate is precipitated as silver bromide. If 6.40 mL of 0.200 M $AgNO_3$ solution is required, what is the mass percentage of bromide in the sample?

(A) 1.28 **(B)** 2.56 **(C)** 5.11 **(D)** 9.15

12. Under which conditions is the solubility of oxygen gas in water the greatest?

	Pressure	**Temperature**
(A)	high	high
(B)	high	low
(C)	low	high
(D)	low	low

13. Which pure compounds form intermolecular hydrogen bonds?

I. HF
II. H_2S
III. CH_4

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

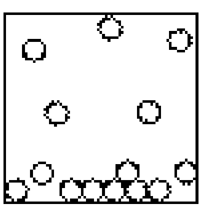
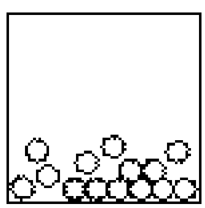
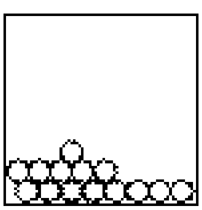
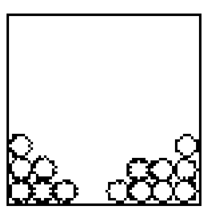
14. What is the molar mass of a gas if 10.0 grams of it occupy 4.48 liters at 273 K and 101.3 kPa (1.00 atm)?

(A) 2.00 g/mol **(B)** 25.0 g/mol
(C) 50.0 g/mol **(D)** 100. g/mol

15. Which process requires the greatest amount of energy for 1 mole of H_2O?

(A) breaking the O-H bonds **(B)** melting
(C) evaporating **(D)** subliming

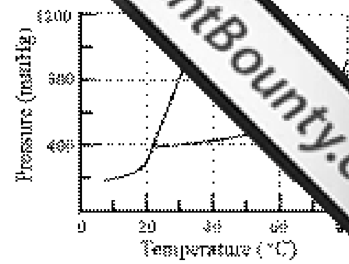
16. If the circles represent molecules, which diagram provides the best molecular level representation of a pure solid in the process of melting?

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

17. Which substance boils at the highest temperature?

(A) CH_3Cl **(B)** CH_2Cl_2
(C) $CHCl_3$ **(D)** CCl_4

18. What can be concluded about the substance represented by this phase diagram?



(A) The normal boiling point of the liquid is 80 ˚C.
(B) The solid is more dense than the liquid.
(C) The solid sublimes at temperatures above 20 ˚C.
(D) The vapor can be converted to liquid by compressing it at temperatures below 20 ˚C.

19. A chemical reaction is carried out twice with the same quantity of reactants to form the same products but the pressure is different for the two experiments. Which does not change?

(A) K_P **(B)** heat released
(C) $\Delta T_{surroundings}$ **(D)** work done

20. Which of these conversions has a positive $\Delta S°$?

I. combustion of charcoal
II. condensation of $Br_2(g)$
III. precipitation of AgCl(s)

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

21. Given these reactions:

$A \rightarrow 2B \quad \Delta H = 40$ kJ
$B \rightarrow C \quad \Delta H = -50$ kJ
$2C \rightarrow D \quad \Delta H = -20$ kJ

Calculate ΔH for the reaction; $D + A \rightarrow 4C$.

(A) –100 kJ **(B)** –60 kJ
(C) –40 kJ **(D)** 100 kJ

22. Hydrazine, N_2H_4, contains a N-N single bond and 4 N-H bonds. Use bond energies to calculate ΔH in kJ for the reaction;
$N_2 + 2H_2 \rightarrow N_2H_4$.

Bond Energies ($kJ \cdot mol^{-1}$)	
H–H	436
N–H	389
N–N	159
N=N	418
N≡N	941

(A) –425 kJ **(B)** –98 kJ **(C)** 98 kJ **(D)** 425 kJ

23. An ice cube of unknown mass at 0 ˚C is added to 265 g of H_2O at 25.00˚C in a calorimeter. If the final temperature of the resulting H_2O is 21.70˚C, what is the mass of the ice cube?

Properties of Water	
C_p	4.18 $J \cdot g^{-1} \cdot K^{-1}$
ΔH_{fusion}	333 $J \cdot g^{-1}$

(A) 2.47 g **(B)** 8.63 g **(C)** 10.3 g **(D)** 11.0 g

24. Which reaction is spontaneous at all temperatures at standard pressure and concentration?

(A) exothermic reaction with a decrease in entropy

(B) exothermic reaction with an increase in entropy

(C) endothermic reaction with a decrease in entropy

(D) endothermic reaction with a increase in entropy

25. When 100. mL of 1.0 M HCl is added to a 2.0 g piece of $CaCO_3$, CO_2 is produced at a certain rate. Which of the changes below will NOT increase the rate of this reaction?

(A) adding 100. mL of 2.0 M HCl in place of 100. mL of 1.0 M HCl

(B) heating the 100. mL of 1.0 M HCl before adding it to the $CaCO_3$

(C) adding 100. mL of 1.0 M HCl to 2.0 g of powdered $CaCO_3$

(D) adding 150. mL of 1.0 M HCl in place of 100. mL of 1.0 M HCl

26. $2N_2H_4(g) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$

If $N_2H_4(g)$ disappears at a rate of 0.12 mol·L·min, at what rate does $N_2(g)$ appear?

(A) 0.080 $mol{\cdot}L^{-1}{\cdot}min^{-1}$ **(B)** 0.12 $mol{\cdot}L^{-1}{\cdot}min^{-1}$

(C) 0.18 $mol{\cdot}L^{-1}{\cdot}min^{-1}$ **(D)** 0.36 $mol{\cdot}L^{-1}{\cdot}min^{-1}$

27. Use the data to determine the orders of A and B in the reaction; A + B → products

Experiment	[A], $mol{\cdot}L^{-1}$	[B], $mol{\cdot}L^{-1}$	rate, $mol{\cdot}L^{-1}{\cdot}s^{-1}$
1	0.10	0.10	0.0090
2	0.20	0.10	0.036
3	0.10	0.20	0.018

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

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

28. $2NO(g) + Cl_2(g) \rightarrow 2NOCl$ $\Delta H = -38$ kJ

If the activation energy for the forward reaction is 62 kJ, what is the activation energy for the reverse reaction?

(A) 24 kJ **(B)** 38 kJ **(C)** 62 kJ **(D)** 100 kJ

29. What is the order of a reaction if the rate constant has the units $L{\cdot}mol^{-1}{\cdot}s^{-1}$?

(A) zero **(B)** first

(C) second **(D)** third

30. An iron catalyst is used in the Haber p… h gaseous N_2 and H_2 react to produce NH_3 … le of this catalyst?

(A) It provides a pathway with a lower activation energy.

(B) It increases the equilibrium constant of the reaction.

(C) It raises the kinetic energies of the reactants.

(D) It interacts with the NH_3.

31. $2NO_2(g) + 7H_2(g) \rightleftharpoons 2NH_3(g) + 4H_2O(l)$

What is the correct equilibrium expression for this reaction?

(A) $K_c = \dfrac{[NH_3]^2}{[NO_2]^2[H_2]^7}$ **(B)** $K_c = \dfrac{[NO_2]^2[H_2]^7}{[NH_3]^2}$

(C) $K_c = \dfrac{[NH_3]^2[H_2O]^4}{[NO_2]^2[H_2]^7}$ **(D)** $K_c = \dfrac{[NH_3]^2[H_2O]^4}{[NO_2]^2}$

32. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

The equilibrium reaction shown is endothermic as written. Which change will increase the amount of NO_2 at equilibrium?

(A) adding a catalyst

(B) decreasing the temperature

(C) increasing the volume of the container

(D) adding an inert gas to increase the pressure

33. Which weak acid has the strongest conjugate base?

(A) acetic acid ($K_a = 1.8{\times}10^{-5}$)

(B) formic acid ($K_a = 1.8{\times}10^{-4}$)

(C) hydrofluoric acid ($K_a = 6.8{\times}10^{-4}$)

(D) propanoic acid ($K_a = 5.5{\times}10^{-5}$)

34. What is the pH of a 0.20 M HA solution ($K_a = 1.0{\times}10^{-6}$) that contains 0.40 M NaA?

(A) 3.15 **(B)** 3.35 **(C)** 5.70 **(D)** 6.30

35. A 0.1 M solution of which salt will have a pH less than 7?

(A) NaCl **(B)** NH_4Br

(C) KF **(D)** NaO_2CCH_3

36. What is the $[Mg^{2+}]$ in 0.10 M NaF that is saturated with MgF_2 at 25 °C?

	K_{sp}
MgF_2	6.4×10^{-9}

(A) 0.050 M **(B)** 1.9×10^{-3} M
(C) 1.2×10^{-3} M **(D)** 6.4×10^{-7} M

37. Which change represents an oxidation?

(A) $NO_2^- \rightarrow N_2$ **(B)** $VO^{2+} \rightarrow VO_3^-$
(C) $ClO^- \rightarrow Cl^-$ **(D)** $CrO_4^{2-} \rightarrow Cr_2O_7^{2-}$

38. What is the oxidation number of Mo in MoO_2Cl_2?

(A) 0 **(B)** +3 **(C)** +5 **(D)** +6

39. What is the coefficient for H^+ when the half equation is balanced with the smallest whole number coefficients?

$$\_\_\ S^{2-} + \_\_\ H_2O \rightarrow \_\_SO_2 + \_\_H^+ + \_\_e^-$$

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

40. What is the E° value for the voltaic cell constructed from the half-cells?

E° (V)	
$Zn^{2+} + 2e^- \rightarrow Zn$	–0.762
$Tl^+ + e^- \rightarrow Tl$	–0.336

(A) 0.090 V **(B)** 0.426 V
(C) 1.098 V **(D)** 1.434 V

41. Which is a consistent set of values for a specific redox reaction carried out under standard conditions?

	$E°$	$\Delta G°$	description
(A)	+	–	spontaneous
(B)	–	+	spontaneous
(C)	+	+	nonspontaneous
(D)	–	–	nonspontaneous

42. During the electrolysis of a dilute solution of sulfuric acid, what substance is produced at the anode?

(A) hydrogen **(B)** hydrogen sulfide
(C) oxygen **(D)** sulfur dioxide

43. Which metal is the most reactive?

(A) silver **(B)** lead
(C) iron **(D)** cesium

44. Which element has the largest first ionization energy?

(A) Li **(B)** B **(C)** N **(D)** Na

45. All of the energy levels listed are allo

(A) 3f. **(B)** 4d. **(C)** 5p.

46. A sulfur atom has the electron configuration: $1s^22s^22p^63s^23p^4$. How many orbitals in this ground atom are occupied by at least one electron?

(A) 12 **(B)** 9 **(C)** 8 **(D)** 5

47. The shapes of s and p orbitals are determined by which quantum number(s)?

I. n
II. l
III. m_l

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

48. What are the elements called for which the 4f subshell is being filled?

(A) transition metals **(B)** metalloids
(C) lanthanides **(D)** actinides

49. Which ionic compound has the smallest lattice energy?

(A) NaF **(B)** MgO **(C)** AlN **(D)** $MgCl_2$

50. Which species have one or more atoms that violate the octet rule?

I. NO
II. SF_2
III. PF_4^+

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

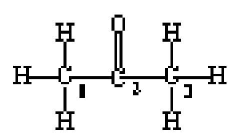
51. In which species is the carbon-nitrogen bond the shortest?

(A) CH_3NH_2 **(B)** CH_2NH
(C) $(CH_3)_4N^+$ **(D)** CH_3CN

52. In which species is resonance most useful in explaining the observed bond lengths?

(A) NF_3 **(B)** NH_4^+ **(C)** NO_2^+ **(D)** NO_2^-

53. Which description best represents the hybridization of the C_1 and C_2 atoms?



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

54. Polar molecules include which of those listed?

I.	CO_2
II.	$COCl_2$
III.	CH_2Cl_2

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

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

55. Which is an example of an aromatic compound?

(A) acetylene **(B)** benzene

(C) polyethylene **(D)** propanone

56. Which can exist as geometric isomers?

(A) 1,1-dichloroethane **(B)** 1,1-dichloroethene

(C) 1,2-dichloroethane **(D)** 1,2-dichloroethene

57. Which substance is formed when $K_2Cr_2O_7$ is added to C_2H_5OH in acid solution?

(A) C_2H_6 **(B)** CH_3COOH

(C) $K^+C_2H_5O^-$ **(D)** $C_2H_5OC_2H_5$

58. Which functional group, present in simple sugars, is responsible for their high solubility in water?

(A) –OH **(B)** –COOH

(C) $–CONH_2$ **(D)** $–NH_2$

59. Which family of compounds is used most frequently as flavoring agents?

(A) acids **(B)** alkenes

(C) esters **(D)** ethers

60. In addition to carbon, hydrogen and oxygen, which element is found in all amino acids?

(A) chlorine **(B)** nitrogen

(C) phosphorus **(D)** sulfur

END OF TEST

National Chemistry Olympiad
LOCAL SECTION EXAM 2006
KEY

Number	Answer	Number	Answer
1.	D	31.	A
2.	C	32.	C
3.	B	33.	A
4.	C	34.	D
5.	A	35.	B
6.	B	36.	D
7.	D	37.	B
8.	B	38.	D
9.	D	39.	B
10.	D	40.	B
11.	C	41.	A
12.	B	42.	C
13.	A	43.	D
14.	C	44.	C
15.	A	45.	A
16.	B	46.	B
17.	D	47.	B
18.	B	48.	C
19.	A	49.	A
20.	A	50.	A
21.	C	51.	D
22.	C	52.	D
23.	B	53.	C
24.	B	54.	D
25.	D	55.	B
26.	C	56.	D
27.	B	57.	B
28.	D	58.	A
29.	C	59.	C
30.	A	60.	B