2007 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.

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		

CONSTANTS

$R = 8.314 \ \text{J·mol}$

$R = 0.0821 \ \text{L·atm·mol}$

$1 \ F = 96,500 \ \text{C·mol}^{-}$

$1 \ F = 96,500 \ \text{J·V}^{-1}\text{·mol}^{-1}$

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

$h = 6.626 \times 10^{-34} \ \text{J·s}$

$c = 2.998 \times 10^8 \ \text{m·s}^{-1}$

$0 \ °C = 273.15 \ K$

$1 \ \text{atm} = 760 \ \text{mmHg}$

EQUATIONS

$$E = E° - \frac{RT}{nF}\ln Q$$

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

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

PERIODIC TABLE OF THE ELEMENTS

1 1A																	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 **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, make sure your answer is clearly legible on the answer she... #2 pencil. For Scantron® style sheets, make a heavy, full mark, but no stray marks. If you decide to change an answe... unwanted answer very carefully.

- There is only one correct answer to each question. Any questions for which more than one response is indicated **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 compound is most soluble in water?

   (A) $AgCl$ (B) Ag_2CO_3 (C) $BaCl_2$ (D) $BaCO_3$

2. Which piece of laboratory equipment should be used to deliver a 10.00 mL sample of acid from a stock container to a flask for a titration?

   (A) 1.0 mL Beral pipet used 10 times

   (B) 10 mL graduated cylinder

   (C) 10 mL volumetric pipet

   (D) 25 mL beaker

3. When solid KOH is mixed with solid NH_4Cl a gas is produced. Which gas is it?

   (A) Cl_2 (B) H_2 (C) HCl (D) NH_3

4. An experiment is carried out to determine the molar mass of a compound by the freezing point depression method using the equation

   $$MM = 7.05 \frac{\text{mass solute}}{\Delta T \times \text{kg solvent}}$$

   The data below are collected.

Mass of empty test tube	42.0 g
Mass of test tube and solvent	73.6 g
Mass of solute dissolved in solvent	2.000 g
Freezing point of pure solvent	78.1 °C
Freezing point of solution	77.6 °C

   How many significant figures can be reported for the molar mass of the solute?

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

5. Which compound forms a colorless solution when dissolved in H_2O?

   (A) $Co(NO_3)_2$ (B) $KMnO_4$

   (C) $Na_2Cr_2O_7$ (D) $ZnCl_2$

6. If an individual spills some 8 M H_2SO_4 on her/his arm, what treatment should be used?

   (A) Neutralize it immediately with a paste of NaOH in H_2O.

   (B) Rinse it with H_2O followed by a dilute solution of $NaHCO_3$.

   (C) Wash it with a solution of concentrated aqueous NH_3.

   (D) Wrap it tightly with gauze coated with petroleum jelly.

7. A saturated aqueous solution of sucrose, $C_{12}H_{22}O_{11}$, contains 525 g of sucrose (molar mass 342) per 100. g of water. What is the $C_{12}H_{22}O_{11}/H_2O$ molecular ratio in this solution?

   (A) 5.25/1   (B) 1.54/1

   (C) 1/1   (D) 0.276/1

8. The mineral beryl contains 5.03% beryllium by mass and contains three beryllium atoms per formula unit. Determine the formula mass of beryl.

   (A) 950 g/mol   (B) 537 g/mol

   (C) 270 g/mol   (D) 179 g/mol

9. A 100. mL portion of 0.250 M calcium nitrate solution is mixed with 400. mL of 0.100 M nitric acid solution. What is the final concentration of the nitrate ion?

   (A) 0.180 M   (B) 0.130 M

   (C) 0.0800 M   (D) 0.0500 M

10. According to the equation,

    $N_2O_3(g) + 6H_2(g) \rightarrow 2NH_3(g) + 3H_2O(g)$

    how many moles of $NH_3(g)$ could be formed from the reaction of 0.22 mol of $N_2O_3(g)$ with 0.87 mol of $H_2(g)$?

   (A) 0.29 mol   (B) 0.44 mol

    (C) 0.73 mol   (D) 1.1 mol

11. Water can be decomposed by the passage of an electric current according to the equation

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$
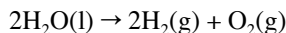
How many moles of $H_2(g)$ can be produced from the passage of 4.8×10^{21} electrons?

(A) 2.00×10^{-3} (B) 4.0×10^{-3}

(C) 8.0×10^{-3} (D) 1.6×10^{-2}

12. This diagram represents the behavior of a pure solvent upon cooling. Which of the diagrams below best represents the cooling curve of a solution in that solvent upon cooling? (Assume that all diagrams are drawn to the same scale.)

(A)

(B)

(C)

(D)
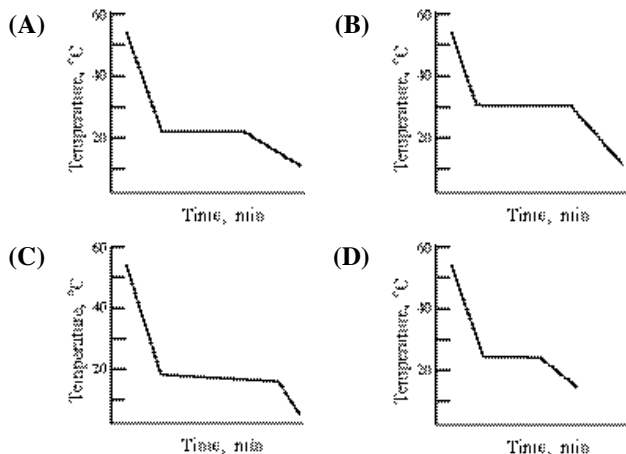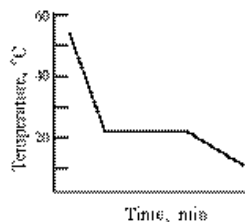
13. All of these are characteristics of MOST ionic compounds in the solid phase EXCEPT

(A) high electrical conductivity

(B) high melting point

(C) solubility in water

(D) insolubility in organic solvents

**14.** Which noble gas effuses approximately twice as fast as Kr?

Molar Mass (g/mol)	
Ne	20.18
Ar	39.95
Kr	83.80
Xe	131.3
Rn	222

(A) Ne   (B) Ar   (C) Xe   (D) Rn

15. Rank the enthalpies of fusion, sublimation, and vaporization for water.

(A) sublimation = vaporization = fusion

(B) vaporization < sublimation < fusion

(C) fusion < sublimation < vaporization

(D) fusion < vaporization < sublimation

16. In this diagram, which bonds represent hydrogen bonds?
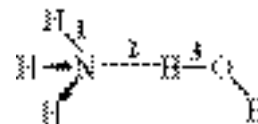
(A) 1 only   (B) 2 only

(C) 1 and 3 only   (D) 1, 2 and 3

17. A sample of C_2H_6 gas initially at 50 °C and 720 mmHg is heated to 100 °C in a container of constant volume. What is the new pressure (in mmHg)?

(A) 360   (B) 623   (C) 831   (D) 1440

18. All of the following properties of liquids increase with increasing strengths of intermolecular forces EXCEPT

(A) boiling point   (B) enthalpy of vaporization

(C) vapor pressure   (D) viscosity

19. The standard enthalpy of formation for $NH_3(g)$ is -46.1 kJ·mol^{-1}. Calculate $\Delta H°$ for the reaction:

$$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$$

(A) -92.2 kJ   (B) -46.1 kJ

(C) 46.1 kJ   (D) 92.2 kJ

20. What is the specific heat capacity of mercury (in J·g^{-1}·°C^{-1}) if a 25.0 g sample requires 19.3 J to raise its temperature from 24.5°C to 30.0°C?

(A) 0.026   (B) 0.032   (C) 0.14   (D) 7.1

21. Which are exothermic processes?

| I. combustion of ethane |
| II. dehydration of barium chloride dihydrate |

(A) I only   (B) II only

(C) both I and II   (D) neither I nor II

22. Which has the highest standard molar entropy?

(A) $O_2(g)$ (B) $SO_2(g)$ (C) $H_2O(l)$ (D) $PbO_2(s)$

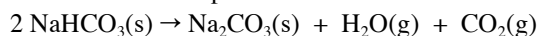**23.** Which is always true for a specific system during a spontaneous reaction?

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

24. Calculate the change in enthalpy (in kJ per mole of CO_2) for the decomposition of sodium hydrogen carbonate from

$\Delta H°_f$ (kJ·mol^{-1})	
$NaHCO_3(s)$	–947.7
$Na_2CO_3(s)$	–1130.9
$H_2O(g)$	–241.8
$CO_2(g)$	–393.5

the standard enthalpies of formation:
$2 NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$

(A) 129.2 **(B)** –818.5 **(C)** –1766.2 **(D)** –3661.6

25. The plot shows the volume of H_2 gas produced as a function of time by the reaction of a given mass of magnesium turnings with excess 1 M HCl. What graph results from the reaction of an equal mass of magnesium turnings with excess 2 M HCl? (Assume all graphs are plotted on the same scale as the one shown above.)

(A)

(B)

(C)

(D)
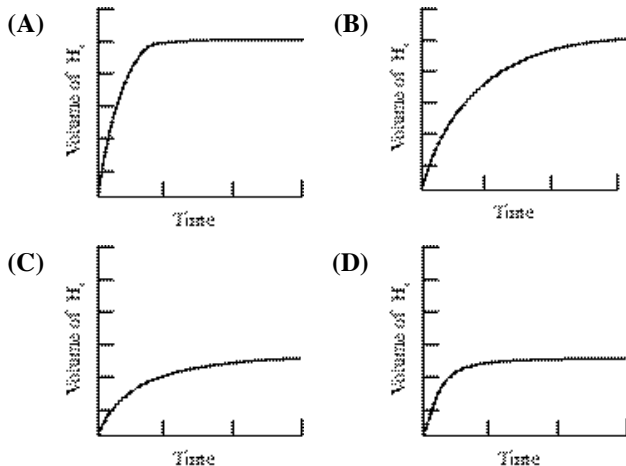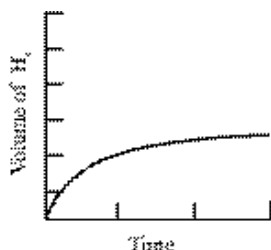
26. $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$
The rate of disappearance of $N_2O_5(g)$ at a certain temperature is 0.016 mol·L^{-1}min^{-1}. What is the rate of formation of $NO_2(g)$ (in mol·L^{-1}·min^{-1}) at this temperature?

(A) 0.0080 **(B)** 0.016 **(C)** 0.032 **(D)** 0.064

27. What are the units of the rate constant for a second order reaction?

(A) s^{-1} **(B)** mol·L^{-1}·s^{-1}

(C) L·s·mol^{-1} **(D)** L·mol^{-1}·s^{-1}

28.

If the disappearance of the spheres in this diagram is a first order process, how much time is required to go from the second box to the third box?

(A) 1 min **(B)** 2 min **(C)** 4 min **(D)** 8 min

29. A catalyst affects the rate of a chemical reaction by

(A) increasing the average kinetic energy of the reactants.

(B) increasing the number of collisions between the reactants.

(C) decreasing the energy difference between the reactants and products.

(D) providing an alternate reaction pathway with a lower activation energy.

30. A hypothetical reaction has a rate law of:
Rate = $k[A]^2[B]$.
Which statement about this reaction is most probably correct?

(A) Doubling the concentration of A will double the rate of the reaction.

(B) Tripling [A] will affect the rate twice as much as tripling [B].

(C) The reaction mechanism involves the formation of B_2 at some stage.

(D) The reaction mechanism involves more than one step.

31. For which reaction at equilibrium does a decrease in volume of the container cause a decrease in product(s) at constant temperature?

(A) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

(B) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(C) $HCl(g) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

(D) $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

32. Which is the weakest acid?

(A) ascorbic acid ($K_a = 8.0 \times 10^{-5}$)

(B) boric acid ($K_a = 5.8 \times 10^{-10}$)

(C) butyric acid ($K_a = 1.5 \times 10^{-5}$)

(D) hydrocyanic acid ($K_a = 4.9 \times 10^{-10}$)

33. At 20.0 °C water has $K_W = 6.807 \times 10^{-15}$. What is the pH of pure water at this temperature?

(A) 6.667   (B) 6.920   (C) 7.000   (D) 7.084

34. Which solution has the highest pH?

	K_a
CH_3COOH	1.8×10^{-5}
HCN	5.8×10^{-10}

(A) 0.10 M CH_3COOH (B) 0.10 M HCN

(C) 0.10 M CH_3COOK (D) 0.10 M NaBr

35. What happens to the pH of a buffer solution when it is diluted by a factor of 10?

(A) The buffer pH decreases by 1 unit.

(B) The buffer pH increases by 1 unit.

(C) The change in pH depends on the buffer used.

(D) The pH does not change appreciably.

36. The solubility of PbI_2 is 1.3×10^{-3} mol·L^{-1}. What is the K_{sp} for PbI_2?

(A) 2.2×10^{-9} (B) 8.8×10^{-9}

(C) 1.7×10^{-6} (D) 3.4×10^{-6}

37. For the balanced equation:
$$8H^+(aq) + 5Fe^{2+}(aq) + MnO_4^-(aq)$$
$$\rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$
which statement is correct?

(A) $Fe^{2+}(aq)$ undergoes oxidation

(B) $Fe^{2+}(aq)$ is the oxidizing agent

(C) $H^+(aq)$ undergoes oxidation

(D) $H^+(aq)$ is the oxidizing agent

38. Which species can act as an oxidizing agent but not as a reducing agent?

(A) Cl_2 (B) Cl^- (C) ClO_2^- (D) ClO_4^-

39. What is the oxidation number of Ti in the compound $Na_2Ti_3O_7$?

(A) −2   (B) +4   (C) +6   (D) +12

40. For a galvanic cell involving the half-[...] standard conditions,
$$Au^{3+} + 3e^- \rightarrow Au \qquad E° = 1.[...]$$
$$Tl^+ + e^- \rightarrow Tl \qquad E° = -0.34[...]$$
what is $E°_{cell}$?

(A) 0.48 V   (B) 1.16 V   (C) 1.84 V   (D) 2.5[...]

41. According to the half-reaction table,
$$Sn^{2+} + 2e^- \rightarrow Sn \qquad E° = -0.14 \text{ V}$$
$$Mn^{2+} + 2e^- \rightarrow Mn \qquad E° = -1.03 \text{ V}$$
which species is the better oxidizing agent?

(A) Mn^{2+} (B) Sn^{2+} (C) Mn   (D) Sn

42. The mass of metal deposited by the electrolysis of an aqueous solution of metal ions increases in direct proportion to which property?

| I. electrolysis current |
| II. electrolysis time |
| III. metal ion charge |

(A) I only   (B) III only

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

43. What is the <u>total</u> number of p electrons in a single phosphorus atom in its ground state?

(A) 3   (B) 5   (C) 9   (D) 15

44. Which element has the largest atomic radius?

(A) Br   (B) K   (C) Mg   (D) Na

45. Which pair of symbols identifies two elements that are metalloids?

(A) B and Ge   (B) Mg and Si

(C) P and As   (D) Ti and V

46. Which pair of symbols represents nuclei that have the same number of neutrons?

(A) $^{56}_{26}Fe$ and $^{58}_{28}Ni$ (B) $^{58}_{26}Fe$ and $^{56}_{26}Fe^{2+}$

(C) $^{57}_{27}Co$ and $^{57}_{28}Ni$ (D) $^{57}_{28}Ni$ and $^{58}_{28}Ni$

47. Green light has a wavelength that is slightly shorter than that of

(A) gamma rays.   (B) orange light.

(C) violet light.   (D) X-rays.

48. Which is the electron configuration for an Fe(III) ion in its ground state?

(A) [Ar] $3d^5$ (B) [Ar] $3d^6$

(C) [Ar] $4s^2 3d^3$ (D) [Ar] $4s^2 3d^6$

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49. In which species does the central atom have one or more lone pairs of valence electrons?

(A) $AlCl_4^-$ (B) CO_2 (C) PCl_4^+ (D) SO_2

50. Which substance has both covalent and ionic bonds?

(A) $NH_4Br(s)$ (B) $KI(s)$

(C) $CH_2Cl_2(l)$ (D) $SiF_4(g)$

51. Which has the largest bond dissociation energy?

(A) H–F (B) H–Cl (C) H–Br (D) H–I

52. The O–N–O bond angle in the nitrite ion, NO_2^-, is closest to

(A) 180°. (B) 150°. (C) 120°. (D) 109°.

53. Which is a resonance form of the Lewis structure shown here?

$$[\overset{..}{\underset{..}{S}}\text{:C:::N}]^-$$

I. $[\overset{..}{\underset{..}{S}}\text{:N:::C}]^-$ II. $[\overset{..}{\underset{..}{S}}\text{:::C:N}]^-$

(A) I only (B) II only

(C) Both I and II (D) Neither I nor II

54. What is the geometry of the fluorine atoms around the boron atom in BF_4^-?

(A) planar (B) see-saw

(C) tetrahedral (D) triangular pyramidal

55. What is the molecular formula for a saturated compound named 2,2,4-trimethylpentane?

(A) C_7H_{14} (B) C_8H_{14} (C) C_8H_{16} (D) C_8H_{18}

56. How many different compounds have [the formula] C_3H_8O?

(A) one (B) two (C) three

57. Which functional group does NOT contain an oxyg[en]?

(A) alcohol (B) aldehyde

(C) amide (D) amine

58. How many pi bonds are present in a molecule of 1-butyne?

(A) one (B) two (C) three (D) four

59. Which is NOT an example of an addition polymer?

(A) polyethylene (B) polyethylene terephthalate

(C) polystyrene (D) polyvinyl chloride

60. The conversion of glucose to ethanol is represented:
$$x\ C_6H_{12}O_6 \rightarrow y\ C_2H_5OH\ +\ z\ CO_2$$
What are the coefficients x, y, z, respectively, in the balanced equation?

(A) 1, 2, 2 (B) 1, 3, 3 (C) 1, 1, 4 (D) 2, 4, 2

END OF TEST

Olympiad 2007 Local Section

KEY

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