

AMERICAN CHEMICAL SOCIETY
2014 VIRGINIA SECTION
CHEMISTRY OLYMPIAD
FIRST YEAR EXAM

DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records their responses. All answers are to be marked on the answer sheet. Each student should be provided the test booklet, Periodic Table with explanation of abbreviations, constants and equations and answer sheet, all of which must be turned in upon completion of the exam.

Students are allowed to use calculators (the calculator may be either programmable or non programmable) and the student should be given at least 90 minutes to complete the exam.

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO

This is a 60 question multiple-choice exam with four or five choices for each question. There is only one correct or best answer to each question. When you select your answer, blacken completely the corresponding space on the answer sheet. If you wish to change an answer, be sure to erase your original answer completely. Any answer that has more than one blackened answer will be incorrect.

Turn in all exam materials when you have completed the exam.

The following information **MUST** be put on the answer sheet:

- a. **Test = First**
- b. **School**
- c. **Student's Last Name followed by Student's First Name.**
- d. **Teacher**

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

CONSTANTS
$R = 8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$R = 0.0821 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$1 F = 96,500 \text{ C}\cdot\text{mol}^{-1}$
$1 F = 96,500 \text{ J}\cdot\text{V}^{-1}\cdot\text{mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$
$c = 2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
$0^\circ\text{C} = 273.15 \text{ K}$
$1 \text{ atm} = 760 \text{ mm Hg}$

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

PERIODIC TABLE OF THE ELEMENTS

1																	18
1A																	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 (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 (Uut) (285)	114 Fl (289)	115 (Uup) (288)	116 Lv (293)	117 (Uus) (294)	118 (Uuo) (294)
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)				

Virginia Chemistry Olympiad First Year Exam

Directions for the First Year Virginia Olympiad Local Section Examination

When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a #2 pencil. If you decide to change an answer, erase the unwanted mark very carefully, and remark the correct space. There is only one correct answer to each question. Any questions for which more than one response is given will not be counted.

Your score will be based on the number of correctly answered questions. It is to your advantage to answer every question.

- If a chemical symbol of a compound is written over the arrow in a chemical reaction, then the compound is most likely a
 - reactant
 - product
 - liquid
 - catalyst
 - gas
- Which of the following is NOT an example of matter?
 - air
 - heat
 - smoke
 - water
 - water vapor
- The oxidation state of boron in B_2O_3 is:
 - +2
 - +3
 - 4
 - 6
 - +6
- A person has a temperature $102.5^\circ F$. What is this temperature on the Kelvin scale?
 - 39.2K
 - 242.1 K
 - 312.3 K
 - 375.65 K
 - 515.25 K
- Which of the following is NOT a physical change?
 - the cutting of cheese
 - the melting of cheese
 - the spoiling of cheese
 - all of the above
 - none of the above.
- Express the sum of 7.68 m and 3.0 m using the correct number of significant digits.
 - 10.68 m
 - 10.7 m
 - 11 m
 - 11.0 m
 - 11.00 m
- Which of the following most directly affects the kinetic energy of an object?
 - its speed
 - its position
 - its volume
 - its area
 - none of the above
- A solution is prepared by dissolving 0.5842g of oxalic acid ($H_2C_2O_4$) in enough water to make 100.0mL of solution. A 10.00mL aliquot of this solution is then diluted to a final volume of 250.0mL. What is the molarity of the final oxalic acid solution?
 - $2.595 \times 10^{-1} M$
 - $5.180 \times 10^{-2} M$
 - $2.595 \times 10^{-3} M$
 - $2.595 \times 10^{-3} M$
 - none of the above.
- The active ingredient in photographic fixer solution contains sodium, sulfur and oxygen. Analysis of a sample shows that the sample contains 0.979 g Na, 1.365 g S, and 1.021 g O. What is the empirical formula of this substance?
 - $Na_2S_2O_3$
 - NaSO
 - $Na_3S_3O_2$
 - $NaSO_3$
 - NaS_2O
- Three different people weigh a standard mass of 2.00 g on the same balance. Each person obtains a reading of 2.32 g for the mass of the standard. These results imply that the balance that was used is ____.
 - accurate
 - precise
 - accurate and precise
 - neither accurate nor precise
 - This cannot be determined
- How many significant figures are there in the measurement 0.00350 kg?
 - two
 - three
 - four
 - five
 - This cannot be determined.

- 12) Express the product of 2.2 mm and 5.00 mm using the correct number of significant digits.
- a) 10 mm^2 b) 11 mm^2
 c) 11.0 mm^2 d) 11.00 mm^2
 e) None of the above
- 13) What is the density of an object having a mass of 8.0 g and a volume of 25 cm^3 ?
- a) 0.32 g/cm^3 b) 2.0 g/cm^3
 c) 3.1 g/cm^3 d) 200 g/cm^3
 e) None of the above
- 14) How much energy is required to heat a block of aluminum ($8.50 \times 10^2 \text{ g}$) from 22.8°C to 94.6°C ? [Aluminum : $c_p = 0.900 \text{ J/(g} \cdot ^\circ\text{C)}$]
- a) 15 kJ b) 0.357 kJ
 c) $1.5 \times 10^1 \text{ kJ}$ d) $2.0 \times 10^3 \text{ kJ}$
 e) None of the above
- 15) Select the correct statement about subatomic particles.
- a) Electrons are negatively-charged and are the heaviest subatomic particle.
 b) Protons are positively-charged and the lightest subatomic particle.
 c) Neutrons have no charge and are the lightest subatomic particle.
 d) The mass of a neutron nearly equals the mass of a proton.
 e) Electrons, protons, and neutrons all have the same mass.
- 16) Which of the following ratios represents a correct conversion factor?
- a) 1 L/10 L b) 1 L/10 g
 c) 1 L/10 dL d) 1 L/10 mL
 e) 1 L/10 cL
- 17) Calculate the change in freezing point at 760 mmHg of a solution containing 2.60 grams of urea, $\text{CO}(\text{NH}_2)_2$, in 50.0 grams of water. (Molal Freezing Constants Water of 1.86)
- a) -0.520°C b) -0.866°C
 c) -1.61°C d) -2.14°C
 e) -3.14°C
- 18) What is the result of converting 48 m to centimeters?
- a) 0.000 48 cm b) 0.48 cm
 c) 4800 cm d) 4 800 000 cm
 e) None of the above
- 19) Which of these statements is FALSE?
- a) Protons have a positive charge.
 b) Electrons are negatively charged and have a mass of 1 amu.
 c) The nucleus of an atom is positively charged.
 d) The neutron is found in the nucleus of an atom.
 e) Both protons and neutrons have a mass of approximately 1 amu.
- 20) All atoms are ____.
- a) positively-charged, with the number of protons exceeding the number of electrons
 b) negatively-charged, with the number of electrons exceeding the number of protons
 c) neutral, with the number of protons equaling the number of electrons
 d) neutral, with the number of protons equaling the number of electrons, which is equal to the number of neutrons
 e) neutral, with the number of protons equaling the number of neutrons, which is equal to half the number of electrons
- 21) How would the rate 60.0 m/s be expressed in km/hr?
- a) 21 600 km/hr b) 216 km/hr
 c) 2.16 km/hr d) 0.216 km/hr
 e) 0.002 16 km/hr
- 22) An atom of an element with atomic number 50 and mass number 120 contains
- a) 50 protons, 50 electrons, and 70 neutrons
 b) 70 electrons, 50 protons, and 50 neutrons
 c) 120 neutrons, 50 protons, and 70 electrons
 d) 70 neutrons, 70 protons, and 50 electrons
 e) None of the above
- 23) If E is the symbol for an element, which two of the following symbols represent isotopes of the same element?
1. ${}_{10}^{20}\text{E}$ 2. ${}_{11}^{20}\text{E}$ 3. ${}_{19}^{21}\text{E}$ 4. ${}_{10}^{21}\text{E}$
- a) 1 and 2 b) 3 and 4
 c) 1 and 4 d) 2 and 3
 e) None of the above

- 24) The compound methyl butanoate smells like apples. Its percent composition is 58.8% C, 9.8% H, and 31.4% O. What is its empirical formula?
 a) $C_6H_{10}O_3$ b) CHO
 c) $C_5H_{10}O$ d) $C_5H_{10}O_3$
 e) $C_5H_{10}O_2$
- 25) The charge on an ion of a Group 7A element is usually ____.
 a) -1 b) 0 c) +1 d) +2 e) +7
- 26) Group A elements are known as the ____.
 a) representative elements
 b) transition elements
 c) inner transition elements
 d) periodic elements
 e) metallic elements
- 27) In which of the following is the symbol for the ion and the number of electrons it contains given correctly?
 a) H^+ has 1 electron.
 b) Br^{1-} has 34 electrons.
 c) Al^{3+} has 16 electrons.
 d) Ca^{2+} has 18 electrons.
 e) S^{2-} has 2 electrons.
- 28) Air contains oxygen, nitrogen, and carbon dioxide and trace amounts of other gases. What is the partial pressure of oxygen (P_{O_2}) at 1 atm of pressure if $P_{N_2} = 593.4$ mmHg, $P_{CO_2} = 0.3$ mmHg, and $P_{others} = 7.1$ mmHg?
 a) 129.2 mmHg b) 149.2 mmHg
 c) 159.2 mmHg d) 169.2 mmHg
 e) 179.2 mmHg
- 29) Which of the following correctly provides the names and formulas of polyatomic ions?
 a) carbonate: HCO_3^{-1} ; bicarbonate: CO_3^{-2}
 b) nitrite: NO^{-1} ; nitrate: NO_2^{-1}
 c) sulfite: S^{-2} ; sulfate: SO_3^{-2}
 d) chlorate: ClO_2^{-} ; chlorite: Cl^{-1}
 e) chromate: CrO_4^{2-} ; dichromate: $Cr_2O_7^{2-}$
- 30) Which set of chemical name and chemical formula for the same compound is correct?
 a) iron(II) oxide, Fe_2O_3
 b) beryllium sulfide, BeS_2
 c) tin(IV) bromide, $SnBr_4$
 d) potassium chloride, K_2Cl_2
 e) aluminum fluoride, AlF_3
- 31) The correct name for the N^{3-} ion is the ____.
 a) nitrate ion b) nitrogen ion
 c) nitride ion d) nitrite ion
- 32) Which of the following elements exists as a diatomic molecule?
 a) neon b) lithium
 c) nitrogen d) sulfur
 e) aluminum
- 33) How many moles of tungsten atoms are there in 4.8×10^{25} atoms of tungsten?
 a) 1.3×10^{-2} b) 8.0×10^1
 c) 1.5×10^4 d) 2.6×10^{23}
 e) 2.9×10^{49}
- 34) Which of the following gas samples would have the largest number of representative particles at STP?
 a) 12.0 L He b) 7.0 L O_2
 c) 0.10 L Xe d) 0.007 L SO_3
 e) 5.5 L N_2O_4
- 35) If 20.0 grams of Ca combines completely with 16.0 grams of S to form a compound, what is the percent composition of Ca in the compound?
 a) 1.25% b) 20.0%
 c) 44.4% d) 55.6%
 e) 80.0%
- 36) If a combination reaction takes place between potassium and chlorine, what is the product?
 a) KCl b) KCl_2 c) K_2Cl
 d) PCl e) PCl_2
- 37) When potassium hydroxide and barium chloride react, potassium chloride and barium hydroxide are formed. The balanced equation for this reaction is.
 a) $KH + BaCl \rightarrow KCl + BaH$
 b) $KOH + BaCl \rightarrow KCl + BaOH$
 c) $2KOH + BaCl_2 \rightarrow 2KCl + Ba(OH)_2$
 d) $KOH + BaCl_2 \rightarrow KCl_2 + BaOH$
 e) $2KOH + 2BaCl_2 \rightarrow 2KCl_2 + 2Ba(OH)_2$
- 38) In the activity series of metals, which metal(s) will displace hydrogen from an acid?
 a) any metal
 b) only metals above hydrogen
 c) only metals below hydrogen
 d) only metals from Li to Na
 e) only gold

- 39) How many moles of aluminum are needed to react completely with 1.8 mol of FeO?
 $2\text{Al}(s) + 3\text{FeO}(s) \rightarrow 3\text{Fe}(s) + \text{Al}_2\text{O}_3(s)$
 a) 0.9 mol b) 1.2 mol
 c) 1.8 mol d) 2.7 mol
 e) 3.6 mol
- 40) A double-replacement reaction takes place when aqueous cobalt(III)chloride reacts with aqueous lithium hydroxide. One of the products of this reaction would be ____
 a) $\text{Co}(\text{OH})_3$ b) $\text{Co}(\text{OH})_2$
 c) LiCO_3 d) LiCl_3
 e) Cl_3OH
- 41) A deep underground cavern contains 2.24×10^6 L methane gas CH_4 at a pressure of 15.0 atm and a temperature of 42°C . How many grams of methane does this natural gas deposit contain?
 a) 1.30×10^5 g CH_4
 b) 1.30×10^6 g CH_4
 c) 4.16×10^6 g CH_4
 d) 2.08×10^7 g CH_4
 e) 2.08×10^8 g CH_4
- 42) Consider the following balanced equation:
 $4\text{NH}_3(g) + 6\text{NO}(g) \rightarrow 5\text{N}_2(g) + 6\text{H}_2\text{O}(g)$
 How many liters of NH_3 are needed to react completely with 30.0 L of NO (at STP)?
 a) 7.50 L b) 20.0 L
 c) 25.0 L d) 30.0 L
 e) 45.0 L
- 43) Calculate the wavelength of the yellow light emitted by a sodium lamp if the frequency of the radiation is $5.10 \times 10^{14} \text{ s}^{-1}$
 a) 5.88×10^{-4} cm b) 2.94×10^{-4} cm
 c) 5.10×10^{-5} cm d) 2.94×10^{-5} cm
 e) 5.88×10^{-5} cm
- 44) Lead (II) nitrate can be decomposed by heating. What is the percent yield of the decomposition reaction if 9.9 g $\text{Pb}(\text{NO}_3)_2$ is heated to give 5.5 g?
 $2\text{Pb}(\text{NO}_3)_2(s) \rightarrow 2\text{PbO}(s) + 4\text{NO}_2(g) + \text{O}_2(g)$
 a) 18% b) 44%
 c) 56% d) 67%
 e) 82%
- 45) When the following equation is balanced, $\text{KClO}_3(s) \rightarrow \text{KCl}(s) + \text{O}_2(g)$ the coefficient of KClO_3 is
 a) 1 b) 2 c) 3 d) 4 e) 6
- 46) Which of the following is NOT a true statement concerning limiting and excess reagents?
 a) The amount of product obtained is determined by the limiting reagent.
 b) A balanced equation is necessary to determine which reactant is the limiting reagent.
 c) Some of the excess reagent is left over after the reaction is complete.
 d) The reactant that has the smallest given mass is the limiting reagent.
 e) Adding more of the limiting reagent to the reaction chamber will cause more product to be produced.
- 47) The change in enthalpy can be calculated for a given chemical reaction with the help of the chart giving the standard heats of formation. The change in enthalpy is equal to.
 a) ΔH_f° of products minus ΔH_f° of reactants
 b) ΔH_f° of products plus ΔH_f° of reactants
 c) ΔH_f° of reactants minus ΔH_f° of products
 d) ΔH_f° of products divided by ΔH_f° of reactants
 e) ΔH_f° of reactants divided by ΔH_f° of products
- 48) As a lump of sugar dissolves in a beaker of water, the entropy of the sugar and water system
 a) increased b) decreases
 c) remains the same
 d) depends on the temperature of the water
- 49) When solid ammonium chloride is dissolved in a beaker of water, the temperature of the mixture decreases. The reaction occurring in the beaker is
 a) exothermic and not spontaneous
 b) endothermic and not spontaneous
 c) exothermic and spontaneous
 d) endothermic and spontaneous.

- 50) The pH of a solution is 3.7. What is the hydrogen ion concentration?
- 1×10^{-4} mol/L
 - 1×10^{-7} mol/L
 - 2×10^{-4} mol/L
 - 2×10^{-6} mol/L
 - 3×10^{-4} mol/L
- 51) Consider the reaction:
 $2 \text{SO}_3(\text{g}) \rightarrow 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g})$.
 Given the following information, calculate ΔG for this reaction at 25°C and 1 atm.
- | Free Energies of Formation (Kcal/mol) | |
|---------------------------------------|-------|
| $\text{SO}_2(\text{g})$ | -71.8 |
| $\text{SO}_3(\text{g})$ | -88.5 |
| $\text{O}_2(\text{g})$ | 0.0 |
- 71.8 kcal
 - 88.5 kcal
 - 33.4 kcal
 - 33.4 kcal
 - 16.7 kcal
- 52) Give the signs you would expect for ΔG , ΔH , and ΔS for the dissolving of a small amount of NaNO_2 in water (the solution becomes cold).
- all positive
 - all negative
 - ΔG negative, ΔH positive, ΔS positive
 - ΔG , negative, ΔH positive, ΔS negative
 - ΔG positive, ΔH negative, ΔS positive
- 53) Consider following reaction
 $\text{Ba}(\text{s}) + \text{F}_2(\text{g}) \rightarrow \text{BaF}_2$
 Which of the following statements is false?
- The barium atom is gaining electrons, therefore it is oxidized.
 - The fluorine atom is gaining electrons, therefore it is oxidized.
 - The barium atom is losing electrons, therefore it is oxidized.
 - The fluorine atom is losing electrons, therefore it is oxidized.
 - none of these
- 54) On a cold day water vapor condenses to form frost. This represents an___
- entropy increase and energy increase
 - entropy increase and energy decrease
 - entropy decrease and energy increase
 - entropy decrease and energy decrease
- 55) Calculate the energy required to produce 6.0 mol Cl_2O_7 on the basis of the following balanced equation:
 $2\text{Cl}_2(\text{g}) + 7 \text{O}_2(\text{g}) + 130 \text{ kcal} \rightarrow 2 \text{Cl}_2\text{O}_7(\text{g})$
- 12 kcal
 - 21 kcal
 - 43 kcal
 - 130 kcal
 - 390 kcal
- 56) In the reaction
 $2\text{Ca}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CaO}(\text{s})$
 calcium is _____.
- reduced
 - electrolyzed
 - synthesized
 - oxidized
 - none of these
- 57) Spontaneous reactions ____
- always give off free energy
 - always take place at a rapid rate
 - always result in increased disorder of the system
 - are always exothermic
 - always absorb free energy
- 58) The diameter of a hydrogen nucleus is 1.0×10^{-3} pm and its mass is 1.67×10^{-24} g. What is the density of the nucleus in grams per cubic centimeter?
- 3.2×10^{12} g/cm³
 - 3.2×10^{15} g/cm³
 - 3.2×10^{18} g/cm³
 - 3.2×10^{21} g/cm³
 - 3.2×10^{24} g/cm³
- 59) One mole of hydrogen gas and 1 mole of iodine are sealed in a 1-L flask and allowed to react at 450°C. At equilibrium 1.56 moles of hydrogen iodide is present. Calculate the K_{eq} for the reaction
 $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$
- 10
 - 20
 - 30
 - 40
 - 50
- 60) What is the deBroglie wavelength associated with a 100.0 gram baseball traveling at 35.0 m/s?
- 7.27×10^{-11} m
 - 1.9×10^{-11} m
 - 1.9×10^{-34} m
 - 7.27×10^{-11} m
 - 7.27×10^{-34} m

END OF TEST

