Worldwide Youth in Science and Engineering

2012 Academic Challenge

CHEMISTRY TEST - SECTIONAL

This Test Consists of 40 Questions

Chemistry Test Production Team
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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. Only one oval should be marked to answer each question. Multiple ovals will automatically be graded as incorrect answers.

Be sure ovals are marked as ● , not ⊙ , ◐ , ◑ , etc.

If you wish to change an answer, erase your first mark completely before marking your new choicE)

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

***** TIME: 40 MINUTES *****

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Periodic Table of the Elements

1A												3A	4A	5A	6A	7A	8A
1 H 1.008	2A																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 65.38	31 Ga 69.72	32 Ge 72.59	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 183.9	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 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

*Lanthanides	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
**Actinides	90 Th 232.0	91 Pa (231)	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 (260)

Potentially Useful Information

$q = m \bullet C_s \bullet \Delta T$

$\Delta T_f = - i K_f \bullet m$

$\Delta T_b = i K_b \bullet m$

$S_{gas} = k_H \bullet P_{gas}$

$P_{solvent} = C_{solvent} \bullet P°_{solvent}$

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

$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt$

$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$

$[A]_t - [A]_0 = -kt$

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

$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H_{rxn}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$pH = -\log [H_3O^+]$

$pOH = -\log [OH^-]$

$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$

$\Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

$\Delta E = B\left(\frac{1}{n_f^2} - \frac{1}{n_{fi}^2}\right)$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$F = 96485$ C/mol

$B = -2.18 \times 10^{-18}$ J

$R = 0.08206$ L atm/mol K; 8.3145 J/mol K

$N_A = 6.022 \times 10^{23}$

1.0 kg = 2.2 lb

1 atm = 101,325 Pa = 1.01325 bar

1.0 in = 2.54 cm

1 J = 1 N m = 1 kg m^2 s^{-2} = 0.239 cal

1 lb = 453.59 g

Assume all gases behave ideally unless specifically told to do otherwise
Assume all solutions are aqueous and at 25 °C unless specifically told otherwise
Assume all gases are at STP unless specifically told otherwise

Simple Rules for the Solubility of Salts in Water

1. Most nitrates are soluble.
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble.
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+, Pb^{2+}, and Hg_2^{2+}.
4. Most sulfates are soluble with the exception of Ba^{2+}, Pb^{2+}, Hg_2^{2+}, and Ca^{2+}.
5. Most hydroxide salts are only slightly soluble with the exception of Group 1 hydroxides. Group 2 (Ba^{2+} to Ca^{2+}) are slightly soluble.
6. Most sulfides, carbonates, chromates, and phosphates are only slightly soluble.

WYSE – Academic Challenge
Chemistry Test (Sectional) – 2012

1. Dypingite is a pearly white magnesium containing mineral originally discovered in Sarnum, Norway and fluoresces bright blue under UV-lights (cool!). The formula of dypingite is $Mg_5(CO_3)_4(OH)_2 \cdot 5(H_2O)$. How many grams of dypingite must you have in order to have 15.25 g of magnesium?

   A) 0.1526 g B) 49.63 g C) 60.95 g D) 304.7 g E) 1523 g

2. An element has 5 stable isotopes. The mass and percentage of each are:

89.9043	51.46%
90.9053	11.23%
91.9046	17.11%
93.9061	17.40%
95.9082	2.80%

   The element is which of the following?

   A) Nb B) Y C) Sr D) Zr E) Rb

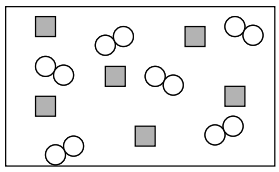
3. If you mix together 25.97 mL of a 3.52 M sugar solution with 55.89 mL of a 6.85 M sugar solution, what will the final concentration of sugar be in the mixture?

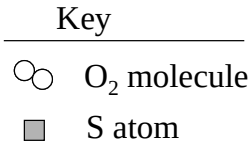
   A) 0.130 M B) 1.58 M C) 4.99 M D) 5.79 M E) 10.4 M

4. A student wants to dissolve the maximum amount of CaF_2 ($K_{sp} = 3.2 \times 10^{-11}$) possible. Into which solution should she dissolve the salt?

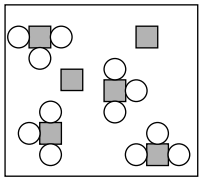
   A) Pure water
   B) 0.01M sodium hydroxide
   C) 0.01M calcium hydroxide
   D) 0.01M hydrofluoric acid
   E) 0.01M hydrochloric acid

5. The diagram represents a mixture of S atoms and O_2 molecules in a closed container.

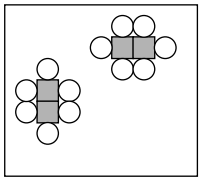




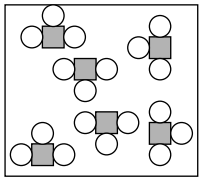
   Which diagram shows the results after this mixture reacts as completely as possible according to the equation: $2S + 3O_2 \rightarrow 2SO_3$



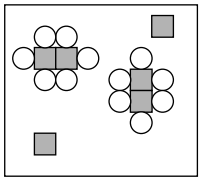
(A)



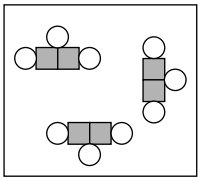
(B)



(C)



(D)



(E)

6. What is the percent yield for the reaction below if 119.3 g of PCl_5 (*MW* = 208.2 g/mol) are formed when 61.3 g of Cl_2 (*MW* = 70.91 g/mol) react with excess PCl_3?

$$PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$$

A) 85.0% B) 66.3% C) 51.4% D) 43.7% E) 23.2%

7. In chemistry we study many types of reactions. Which of the following reactions is labeled **incorrectly**?

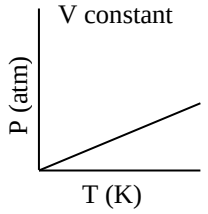
A) $Ca(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2\ NaNO_3(aq)$ Precipitation reaction
B) $H_2SO_4(aq) + 2\ KOH(aq) \rightarrow 2\ H_2O(l) + K_2SO_4(aq)$ Acid-base reaction
C) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$ Combustion reaction
D) $Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(l)$ Oxidation-reduction reaction
E) All of the above reactions (a-d) are labeled correctly.

8. At 27°C and 1.00 atm, the density of a gaseous hydrocarbon is 1.79 g/L. The hydrocarbon is:

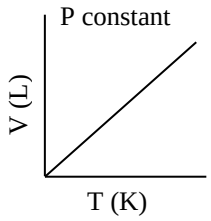
A) CH_4 B) C_2H_4 C) C_2H_6 D) C_3H_8 E) C_4H_{10}

9. Which of the following (a-d) does **not** depict the relationship between the pressure, volume, and temperature for 1 mole of an ideal gas?

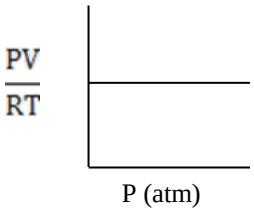
A)



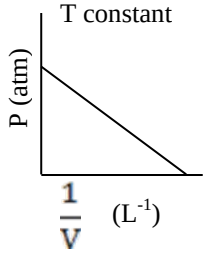
B)



C)

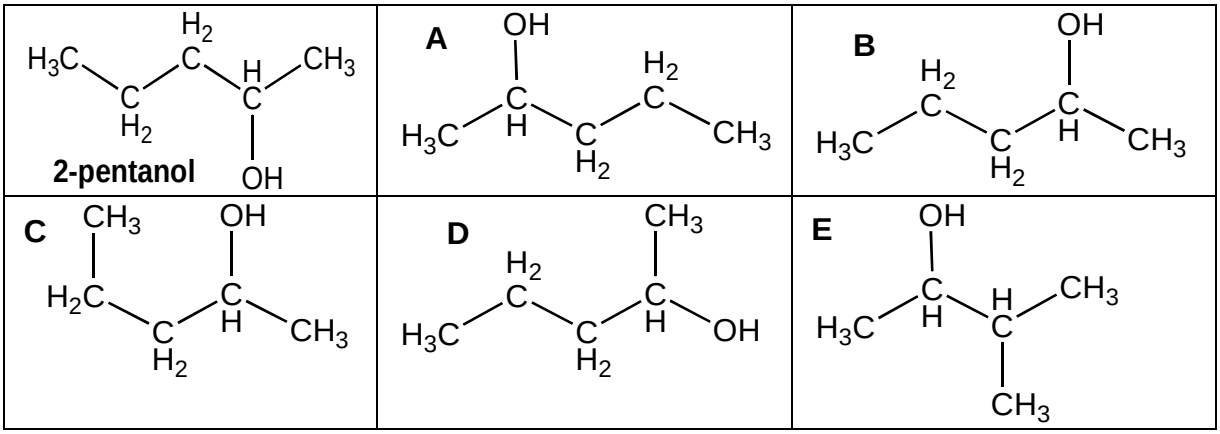


D)



E) All are correct

10. Which of the following molecules is a constitutional isomer of 2-pentanol?



11. Heat is given off when hydrogen burns in air according to the equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Which of the following is responsible for the heat?

A) Breaking hydrogen bonds gives off energy.
B) Breaking oxygen bonds gives off energy.
C) Forming hydrogen-oxygen bonds gives off energy.
D) Both (a) and (b) are responsible.
E) (a), (b), and (c) are responsible.

12. A sample of water is heated at a constant pressure of 1 atm. Initially, the sample is ice at 260 K, and at the end the sample consists of steam at 400 K. In which of the following 5 K temperature intervals would there be the greatest increase in the entropy of the sample?

A) from 260 K to 265 K
B) from 275 K to 280 K
C) from 360 K to 365 K
D) from 370 K to 375 K
E) from 395 K to 400 K

13. How many alpha particles and beta particles must be emitted in the following decay process?

$$^{238}U \rightarrow {}^{206}Pb$$

A) 6 alpha, 8 beta
B) 6 alpha, 6 beta
C) 8 alpha, 8 beta
D) 8 alpha, 6 beta
E) 4 alpha, 4 beta

14. If 1.083 g of element M combine with 1.000 g of oxygen to form MO_3, what element is M? Note that all of the reactants are consumed in the reaction.

A) chromium B) vanadium C) copper D) scandium E) titanium

15. If 10 photons of 7.1×10^{-19} J bombard a metal surface and the threshold energy for this particular metal is 6.9×10^{-19} J, how many electrons will be ejected?

A) 0
B) 1
C) 5
D) 10
E) It is impossible to predict given this information

16. Which one of the following statements about atomic structure and quantum numbers is **incorrect**?

A) In a given atom, the maximum number of electrons having principal quantum number $n = 3$, is 28.
B) The number of orbitals in a given *f* subshell is 7.
C) For $n = 4$, the largest possible value of l is 3.
D) For $n = 4$, the largest possible value of m_l is 3.
E) The following set of quantum numbers for a single orbital is **not** allowed: $n = 3$, $l = 1$, $m_l = -2$.

17. Which of the following compounds is named **correctly**?

A) P_2O_3 - phosphorus oxide
B) MgF_2 - manganese fluoride
C) Ba_3N_2 - barium nitride
D) KNO_2 - potassium nitrate
E) $TaCl_5$ – tantalum(5) chloride

18. Compare the orbital energy levels in hydrogen vs. those for any other multi-electron atom. Which statement is **false**?

A) The orbitals in a given n level for hydrogen are all the same energy, while those in a multi-electron atom can be different.
B) Multi-electron atoms have electrons that experience shielding, while the electron in hydrogen does not.
C) Multi-electron atoms and hydrogen can hybridize their orbitals for bonding.
D) The Bohr model of the atom can only predict the line spectrum of a hydrogen atom, but not those of other atoms.
E) All statements are false.

19. How many hours are required to produce 1.00×10^3 kg of sodium by the electrolysis of molten NaCl with a constant current of 3.00×10^4 A?

A) 19.4 h B) 38.9 h C) 77.8 h D) 141 h E) 1.41×10^5 h

20. For the reaction

$$3A(g) + 2B(g) \rightarrow 2C(g) + 2D(g)$$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate (mol/(L·min))
1	0.200	0.100	6.00×10^{-2}
2	0.100	0.100	1.50×10^{-2}
3	0.200	0.200	1.20×10^{-1}
4	0.300	0.200	2.70×10^{-1}

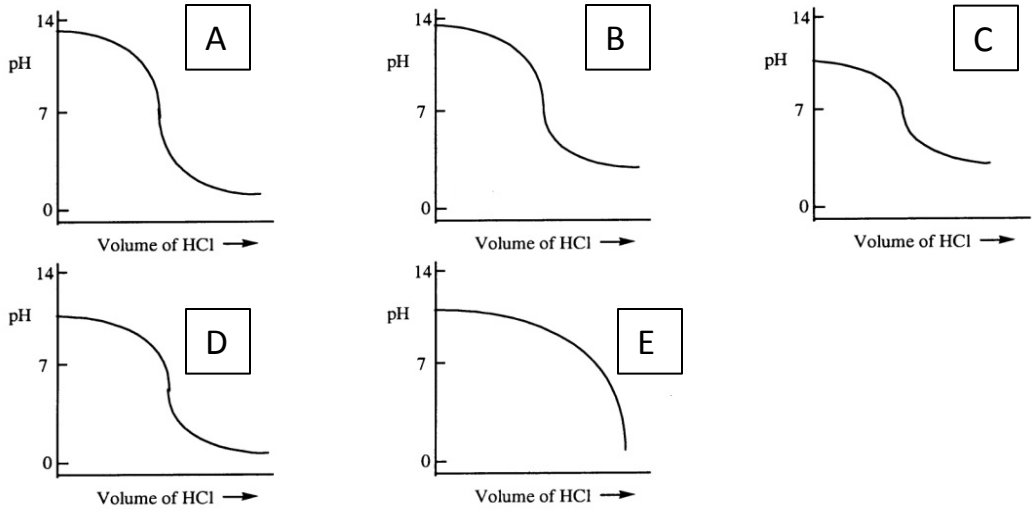
A) Rate = $k[A][B]^2$
B) Rate = $k[A]^2[B]$
C) Rate = $k[A]^3[B]^2$
D) Rate = $k[A]^{1.5}[B]$
E) Rate = $k[A]\,[B]$

21. The rate constant for the reaction shown below is 8.0 $M^{-3}\ s^{-1}$ at 25°C. The reaction is first order in BrO_3^- and first order in Br^-. What is the order with respect to H^+?

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+ \rightarrow 3Br_2(l) + 3H_2O(l)$$

A) 1st order B) 2nd order C) 3rd order D) 4th order E) 5th order

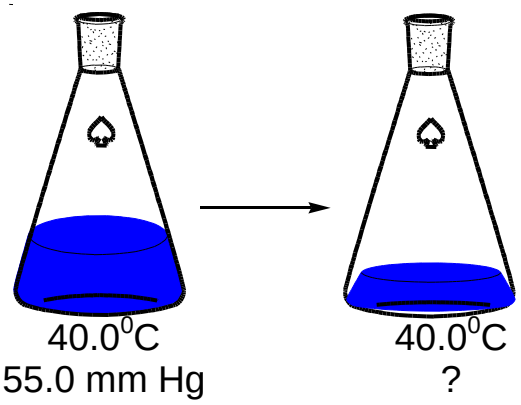
22. Which one of the following is the best representation of the titration curve which will be obtained in the titration of a weak base (0.10 mol L^{-1}) with HCl of the same concentration?



23. Two aqueous solutions are prepared: 2.0 *m* $Cu(NO_3)_2$ and 2.0 *m* NaBr. Which of the following statements is true? Assume both solutions are ideal and both solutes are non-volatile.

A) The $Cu(NO_3)_2$ solution has a higher vapor pressure and lower freezing point than the NaBr solution.
B) The $Cu(NO_3)_2$ solution has a higher vapor pressure and higher freezing point than the NaBr solution.
C) The $Cu(NO_3)_2$ solution has a lower vapor pressure and lower freezing point than the NaBr solution.
D) The $Cu(NO_3)_2$ solution has a lower vapor pressure and higher freezing point than the NaBr solution.
E) Both solutions have the same vapor pressure and freezing point

24. In the closed container shown below, at equilibrium, H_2O has a vapor pressure of 55.0 mm Hg at 40.0 ºC. If we reduce the volume of water by 1/2 and allow the system to reestablish equilibrium what will the vapor pressure be?



A) 11.3 mm Hg
B) 22.5 mm Hg
C) 55.0 mm Hg
D) 110. mm Hg
E) None of the above

25. Which of the following would have the greatest vapor pressure?

A) $CH_3CH_2CH_2CH_2CH_3$
B) $HOCH_2CH_2COH$
C) CH_3OCH_3
D) CH_3OH
E) Cl_2

26. The decomposition of hydrogen peroxide is a first-order process with a rate constant of 1.06×10^{-3} min^{-1}. How long will it take for the concentration of H_2O_2 to drop from 0.0200 *M* to 0.0120 *M*?

A) 2.35 min
B) 7.55 min
C) 481 min
D) 4550 min
E) 31,400 min

27. If 2.0 moles of N_2O_4 are put in a 10.0 L evacuated container, and the following reaction is allowed to come to equilibrium, what is the equilibrium concentration of NO_2?

$$N_2O_4(g) \longleftrightarrow 2NO_2(g) \qquad K = 4.0 \times 10^{-7}$$

A) 4.0×10^{-7} *M*
B) 1.4×10^{-4} *M*
C) 2.8×10^{-4} *M*
D) 4.5×10^{-4} *M*
E) 8.9×10^{-4} *M*

28. Nitrogen and hydrogen combine to form ammonia in the Haber process. Calculate (in kJ) the standard enthalpy change ΔH^o for the reaction written below, using the bond energies given.

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

Bond:	N≡N	H–H	N–H
Bond energy (kJ/mol):	945	432	391

A) -969 kJ/mol
B) -204 kJ/mol
C) -105 kJ/mol
D) 204 kJ/mol
E) 4587 kJ/mol

29. Elements with _____ first ionization energies and _____ electron affinities generally form cations.

A) low, very negative
B) high, positive or slightly negative
C) low, positive or slightly negative
D) high, very negative
E) None of the above

30. Which of the following samples contains the largest number of molecules?

A) 1 g of benzene, C_6H_6
B) 1 g of formaldehyde, CH_2O
C) 1 g TNT, $C_7H_5N_3O_6$
D) 1 g naphthalene, $C_{10}H_8$
E) 1 g of glucose, $C_6H_{12}O_6$

31. A 20.2% by mass aqueous solution of HCl has a density of 1.096 g/ml. Calculate the molarity of the HCl solution.

A) 6.93 M
B) 6.07 M
C) 5.54 M
D) 14.1 M
E) 0.22 M

32. A 30.0-mL sample of an unknown strong base is neutralized after the addition of 12.0 mL of 0.150 M HNO_3 solution. If the unknown base concentration is 0.0300 M, what could the unknown base be?

A) NH_3
B) KOH
C) $Ca(OH)_2$
D) $Al(OH)_3$
E) Could be any of A-D

33. A student isolates the product of a reaction. While analyzing it, she finds it consists of 5 atoms, 4 of which are fluorine, and the shape is a see-saw. Which of the following could be the product?

A) SeF_4 B) BrF_4^- C) PF_4^+ D) NF_4^+ E) XeF_4

34. Which gas sample below will have the **highest** average kinetic energy? Assume you have 1 mole of each sample.

A) Ne (20 g/mol) @ 20°C
B) He (4 g/mol) @ 20°C
C) SO_2 (64 g/mol) @15°C
D) Br_2 (160 g/mol) @ 25°C
E) All of the above have the same kinetic energy.

35. In each of the following pairs, choose the atom or ion with the **smallest** radius.

N and O Rb^+ and Br^- Se and Se^{2-} K and Mg

A) O, Rb^+, Se, Mg
B) N, Rb^+, Se, Mg
C) O, Br^-, Se, K
D) N, Br^-, Se^{2-}, K
E) O, Br^-, Se, Mg

36. A dimerization reaction is one in which two of the same species join together to make a new compound. Calculate $\Delta H°$ for the dimerization of NO_2 below.

$2\ NO_2\ (g) \rightarrow\ N_2O_4\ (g)$ $\Delta H° = ?$
$N_2\ (g)\ +\ 2O_2\ (g) \rightarrow\ 2NO_2\ (g)$ $\Delta H° = 67.7$ kJ
$N_2\ (g)\ +\ 2O_2\ (g) \rightarrow\ N_2O_4\ (g)$ $\Delta H° = 9.7$ kJ

A) 77.4 kJ B) -77.4 kJ C) 58.0 kJ D) -58.0 kJ E) 0 kJ

Questions 37 and 38 relate to the equilibrium below.

$$B_2O_3(s) + 3H_2O(g) \longleftrightarrow B_2H_6(g) + 3O_2(g) \quad \Delta H = 2035 \text{ kJ}, K = 2.8 \times 10^{-2}$$

37. Initially 8.0 mol B_2O_3, 5.0 mol H_2O, 6.0 mol B_2H_6, and 2.0 mol O_2 are mixed in a 1.0 L container. What will happen to the amount of B_2O_3 present as the system reaches equilibrium?

A) It will decrease because the system will shift to the right.
B) It will not change because solids are not involved in the equilibrium.
C) It will not change because the system is already at equilibrium.
D) It will increase because the system will shift to the left.
E) It will decrease because the system will shift to the left.

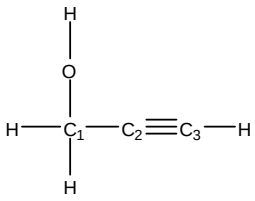
38. After the system has reached equilibrium, which of the following statements is **<u>true</u>** regarding the reaction?

A) Raising the temperature will lower the value of K.
B) Adding more B_2O_3 will cause the reaction to shift to the right.
C) If the container volume is reduced, the system will shift to the left.
D) Removing some $B_2H_6(g)$ will cause the reaction to shift to the left.
E) For this reaction, $K = K_p$.

39. Which of the following compounds contains both ionic and covalent bonds?

A) ClF
B) SO_2
C) NaCl
D) SO_3
E) NaCN

40. How many of the following statements concerning the organic molecule on the right are true? Note that the structure may not be complete.



I. There are 9 σ bonds total in this molecule.
II. This compound has the same empirical and molecular formulae.
III. The carbons labeled 2 and 3 have opposite formal charges.
IV. The carbon-oxygen bond is formed from overlap of an sp^3 orbital on C_1 and an sp orbital on the oxygen.

A) 0 (none are true)
B) 1
C) 2
D) 3
E) 4 (all are true)