



Worldwide Youth in Science and Engineering

2015 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. One oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

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!

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Periodic Table of the Elements

1A	2A											3A							4A							5A							6A							7A							8A																																																																													
1 H 1.008	4 Be 9.012	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 Ac** (227)	89 Ac** (227)	101 Unh	102 Unq	103 Unp	104 Unp	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unp	111 Unp	112 Unp	113 Unp	114 Unp	115 Unp	116 Unp	117 Unp	118 Unp	119 Unp	120 Unp	121 Unp	122 Unp	123 Unp	124 Unp	125 Unp	126 Unp	127 Unp	128 Unp	129 Unp	130 Unp	131 Unp	132 Unp	133 Unp	134 Unp	135 Unp	136 Unp	137 Unp	138 Unp	139 Unp	140 Unp	141 Unp	142 Unp	143 Unp	144 Unp	145 Unp	146 Unp	147 Unp	148 Unp	149 Unp	150 Unp	151 Unp	152 Unp	153 Unp	154 Unp	155 Unp	156 Unp	157 Unp	158 Unp	159 Unp	160 Unp	161 Unp	162 Unp	163 Unp	164 Unp	165 Unp	166 Unp	167 Unp	168 Unp	169 Unp	170 Unp	171 Unp	172 Unp	173 Unp	174 Unp	175 Unp	176 Unp	177 Unp	178 Unp	179 Unp	180 Unp	181 Unp	182 Unp	183 Unp	184 Unp	185 Unp	186 Unp	187 Unp	188 Unp	189 Unp	190 Unp	191 Unp	192 Unp	193 Unp	194 Unp	195 Unp	196 Unp	197 Unp	198 Unp	199 Unp	200 Unp	201 Unp	202 Unp	203 Unp	204 Unp	205 Unp	206 Unp	207 Unp	208 Unp	209 Unp	210 Unp	211 Unp	212 Unp	213 Unp	214 Unp	215 Unp	216 Unp	217 Unp	218 Unp	219 Unp	220 Unp	221 Unp	222 Unp

*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

$$q = m \cdot c_s \cdot \Delta T$$

$$\Delta T_b = i \cdot K_b \cdot m$$

$$P_{\text{solvent}} = X_{\text{solvent}} \cdot P^{\circ}_{\text{solvent}}$$

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

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

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

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

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

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

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

$$\Delta G^{\circ} = -nF\mathcal{E}^{\circ}$$

$$\Pi = MRT$$

$$F = 96485 \text{ C/mol}$$

$$R = 0.08206 \text{ L atm/mol K}; 8.3145 \text{ J/mol K}$$

$$1.0 \text{ kg} = 2.2 \text{ lb}$$

$$1.0 \text{ in} = 2.54 \text{ cm}$$

$$1 \text{ lb} = 453.59 \text{ g}$$

$$c = 2.998 \times 10^8 \text{ m/s}$$

$$\Delta T_f = i \cdot K_f \cdot m$$

$$S_{\text{gas}} = k_H \cdot P_{\text{gas}}$$

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

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

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

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

$$\text{pOH} = -\log [\text{OH}^-]$$

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

$$E_{\text{cell}}^{\circ} = E_{\text{red}}^{\circ} + E_{\text{ox}}^{\circ}$$

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

$$c = \lambda\nu$$

$$\Delta E = h\nu$$

$$K_w = 1.0 \times 10^{-14}$$

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

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

$$1 \text{ atm} = 101,325 \text{ Pa} = 1.01325 \text{ bar}$$

$$1 \text{ J} = 1 \text{ N} \cdot \text{m} = 1 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} = 0.239 \text{ cal}$$

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

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

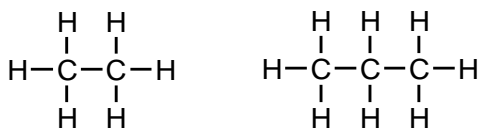
1. Most nitrates are soluble
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+ , Pb^{2+} , and Hg_2^{2+} .
4. Most sulfates are soluble with the exception of Ba^{2+} , Pb^{2+} , Hg_2^{2+} , and Ca^{2+}
5. 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) – 2015

- A company is going to expand and is considering buying a plot of land in Europe. If it wants to have an area of 2.50 square miles, about how much land should it buy, in units of square kilometers, if 1 mile = 1.6093 kilometers?

A. 2.50 km² B. 4.02 km² C. 5.00 km² D. 1.60 km² E. 6.47 km²
- What is the final temperature of 15.0 g of water in a glass at 22.0 °C when 444.7 joules of heat are added? (Consider all energy has been successfully transferred to water and the specific heat capacity of water is 4.184 J/g°C.)

A. 7.0 °C B. 20.0 °C C. 22.4 °C D. 27.0 °C E. 29.1 °C
- The structural formulas of the hydrocarbons CH₃CH₃ and CH₃CH₂CH₃ are presented below.



These species belong to a series known as _____.

- A. isotopes B. allotropes C. homologs D. isomers E. isobars
- What type of reaction is shown below?

$$\text{Cu}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2 \text{Na}^+(\text{aq}) + \text{S}^{2-}(\text{aq}) \rightarrow 2 \text{Na}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + \text{CuS}(\text{s})$$

A. precipitation
B. hydration
C. neutralization
D. oxidation-reduction
E. combustion
 - A compound contains 36.86% N and 63.14% O by mass. What is its empirical formula of this compound?

A. NO B. NO₂ C. N₂O D. NO₃ E. N₂O₃
 - A gaseous solution is made up of 0.289 moles of nitrogen gas and 0.433 moles of oxygen gas. What are the mole fractions of nitrogen and oxygen in that order?

A. 0.278 and 0.722
B. 0.400 and 0.600
C. 0.555 and 0.445
D. 0.0289 and 0.711
E. 0.289 and 0.433

7. What is the mass percent of hydrogen in ethanol, $\text{CH}_3\text{CH}_2\text{OH}$?
- A. 11.1 B. 66.7 C. 23.3 D. 52.2 E. 13.0
8. Suppose 26.0 g of calcium chloride, CaCl_2 , are dissolved in water to make 200.0 mL of solution. How many times greater is the molarity of chloride ions (Cl^-) than the molarity of calcium ions (Ca^{2+}) in the solution?
- A. 2.00 B. 1.20 C. 1.80 D. 0.500 E. 4.00
9. Which of the following half reactions displays the greatest ease in oxidation with the associated potentials?
- A. $\text{Mg}^{2+} + 2 \text{e}^- \rightarrow \text{Mg}; E^\circ = -2.37 \text{ V}$
 B. $\text{F}_2 + 2 \text{e}^- \rightarrow 2 \text{F}^-; E^\circ = 2.87 \text{ V}$
 C. $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}; E^\circ = 0.80 \text{ V}$
 D. $\text{Al}^{3+} + 3 \text{e}^- \rightarrow \text{Al}; E^\circ = -1.66 \text{ V}$
 E. $2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2; E^\circ = 0.00 \text{ V}$
10. Which of the following has a trigonal planar geometry?
- A. CO_2 B. CO C. CH_4 D. CH_2O E. NH_3
11. Which one is the correct distribution of subatomic particles in atoms?
- | <u>Inside the nucleus</u> | <u>Outside of the nucleus</u> |
|---------------------------|-------------------------------|
| A. Neutrons and electrons | Protons |
| B. Protons and electrons | Neutrons |
| C. Protons and neutrons | Electrons |
| D. Electrons | Protons and neutrons |
| E. Neutrons | Electrons and protons |
12. Which of these is the electron configuration of the chloride ion (Cl^-)?
- A. $[\text{Kr}] 5s^2$
 B. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
 C. $1s^2 2s^2 2p^6 3s^2 3p^6$
 D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$
 E. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^6$
13. By definition, the rare-earth elements are elements with a partially filled _____ orbital.
- A. p B. d C. s D. f E. g
14. What is the pOH of an acid if its $[\text{H}^+]$ is 0.025 M?
- A. 1.46 B. 12.40 C. 12.54 D. 1.60 E. 2.50

15. Which of the following represents the **properly balanced** chemical equation for the word equation below?

iron(II) sulfide + hydrochloric acid \rightarrow iron(II) chloride + dihydrogen sulfide

- A. $\text{FeS} + \text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2\text{S}$
 B. $\text{Fe}_2\text{S} + 2 \text{HCl} \rightarrow \text{Fe}_2\text{Cl}_2 + \text{H}_2\text{S}$
 C. $2 \text{FeS} + 4 \text{HCl} \rightarrow 2 \text{FeCl}_2 + 2 \text{H}_2\text{S}$
 D. $\text{FeS} + 2 \text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2\text{S}$
 E. $2 \text{Fe}_2\text{S} + 2 \text{HCl} \rightarrow 2 \text{Fe}_2\text{Cl}_2 + \text{H}_2\text{S}$
16. Knowing the fact that carbon dioxide, CO_2 , is an acidic anhydride, the pH of the natural rain water is expected to be _____.
- A. equal to zero
 B. around 3.50
 C. equal to 7
 D. greater than 7
 E. less than 7
17. Predict the direction in which the following equilibrium will shift if the pressure on the system is decreased by expansion.



- A. Equilibrium will shift to the right.
 B. Equilibrium will shift to the left.
 C. It cannot be predicted, because it depends on a catalyst.
 D. The pressure on the system has no effect on the equilibrium.
 E. It is not possible to predict without additional information.
18. Which of the following describes the ionization energy trend through the periodic table?

In a period _____

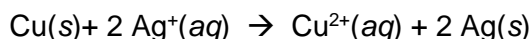
in a column _____

- | | |
|---------------------------------|------------------------------|
| A. increases from left to right | decreases from top to bottom |
| B. increases from left to right | increases from top to bottom |
| C. decreases from left to right | decreases from top to bottom |
| D. decreases from left to right | increases from top to bottom |
| E. remains unchanged | remains unchanged |
19. What is the bond angle of the H-S-H bond in H_2S molecule?
- A. $\sim 90^\circ$ B. $\sim 180^\circ$ C. $\sim 120^\circ$ D. $\sim 109.5^\circ$ E. $\sim 45^\circ$

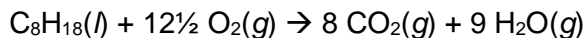
20. The rate law of the following reaction is expressed on its right. Which of the answers is incorrect?



- A. The reaction is zero order with respect to A
 B. The reaction is first order with respect to B
 C. The reaction is second order with respect to C
 D. The reaction overall is a second order
 E. The reaction overall is a third order
21. Which of the following has bond angles of 109.5°?
- A. SeCl₄ B. XeF₄ C. SiF₄ D. SF₄ E. SO₃
22. A sample of 1.00 mole of chlorine gas, Cl₂, is in a steel tank at 40.0°C and 660.0 mmHg pressure. What is the density of the chlorine gas?
- A. 2.40 g/L B. 29.6 g/L C. 2.76 g/L D. 27.1 g/L E. 1.20 g/L
23. In the following reaction, what would take place at the **anode**?



- A. $2 \text{Ag}^+(aq) + 2 e^- \rightarrow 2 \text{Ag}(s)$
 B. $\text{Cu}^{2+}(aq) + 2 e^- \rightarrow 2 \text{Ag}(s)$
 C. $\text{Cu}(s) \rightarrow \text{Cu}^{2+}(aq) + 2 e^-$
 D. $\text{Cu}(s) \rightarrow 2 \text{Ag}^+(aq) + 2 e^-$
 E. $2 \text{Ag}^+(aq) \rightarrow \text{Cu}^{2+}(s)$
24. The best description of an isotope _____
- A. Isotopes have the same number of protons and neutrons.
 B. Isotopes have the same number of protons, but have different numbers of neutrons.
 C. Isotopes are chemically identical, but they differ in mass.
 D. Isotopes have the same mass but they differ in chemical behavior.
- A. A & B B. A & D C. C & D D. B & C E. B & D
25. What is the enthalpy change for the following reaction?



$\Delta H_{\text{rxn}} = \Sigma \text{mol } \Delta H_f^\circ \text{ prod} - \Sigma \text{mol } \Delta H_f^\circ \text{ react}$	$\Delta H_f^\circ \text{ of } \text{C}_8\text{H}_{18}(l) = -269.7 \text{ kJ}$
	$\Delta H_f^\circ \text{ of } \text{CO}_2(g) = -393.5 \text{ kJ}$
	$\Delta H_f^\circ \text{ of } \text{H}_2\text{O}(g) = -241.8 \text{ kJ}$

- A. -365.6 kJ B. -5054.5 kJ C. -905.0 kJ D. -5593.9 kJ E. 365.6 kJ

26. Which chemical name does **not** match with the formula given in the following table?

Name	Formula
Sodium sulfite	Na_2SO_4
Magnesium nitride	Mg_3N_2
Iron(II) phosphate	$\text{Fe}_3(\text{PO}_4)_2$
Dichlorine pentoxide	Cl_2O_5
Dinitrogen tetroxide	N_2O_4

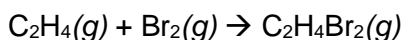
- A. Sodium sulfite
- B. Magnesium nitride
- C. Iron(II) phosphate
- D. Dichlorine pentoxide
- E. Dinitrogen tetroxide

27. Identify the correct statement from the following table.

	ΔG° (kJ)	ΔH° (kJ)
Reaction-I	100	100
Reaction-II	-100	-100

- A. Reaction-I is spontaneous and exothermic
- B. Reaction-II is spontaneous and exothermic
- C. Reaction-I is spontaneous and endothermic
- D. Reaction-I is nonspontaneous and exothermic
- E. Reaction-II is nonspontaneous and exothermic

28. Ethylene (C_2H_4) reacts with bromine gas according to the following equation:



The rate of this reaction is first order in $[\text{C}_2\text{H}_4]$ and third order overall. If the initial concentrations of the reactants are doubled, the rate of the reaction will increase by what factor?

- A. 2
- B. 4
- C. 6
- D. 8
- E. 10

29. Thallium-201 is a radioactive isotope that undergoes first-order decay. When the concentration of ^{201}Tl is 0.0042 M, its half-life is 73.0 hours. What is the half-life of ^{201}Tl when its concentration is 0.0136 M?

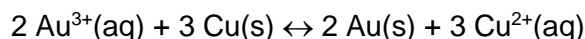
- A. 51.0 hours
- B. 22.5 hours
- C. 123 hours
- D. 236 hours
- E. 73.0 hours

30. If a drop of water is subdivided till the smallest piece that retains the chemical and physical properties of water, it will be a(an) _____.

- A. mixture
- B. molecule
- C. atom
- D. anion
- E. cation

31. Which of the following is true for the osmotic pressure of 0.10 M solutions of NaCl and MgCl₂ at 25 °C?
- Osmotic pressure of both solutions will be the same.
 - Osmotic pressure of 0.10 M NaCl will be lower than that of 0.10 M MgCl₂.
 - Osmotic pressure of 0.10 M NaCl will be higher than that of 0.10 M MgCl₂.
 - Osmotic pressure depends on how the solution is prepared.
 - Osmotic pressure is independent of concentration when the temperature is the same.
32. A mixture of iron, salt and sand can be separated using a magnet, water, a filter paper, and a hot plate. The separation of this mixture _____.
- uses chemical and physical changes or processes
 - uses physical changes/processes
 - uses chemical changes/processes
 - uses precipitation process
 - cannot be done with the materials listed

33. Gold ions react with copper metal to give gold metal and cupric ions.



What is the equilibrium expression for this reaction?

- $K = [\text{Au}^{3+}]^2/[\text{Cu}^{2+}]^3$
 - $K = [\text{Au}]^2[\text{Cu}^{2+}]^3/[\text{Au}^{3+}]^2[\text{Cu}]^3$
 - $K = [\text{Au}^{3+}]^2[\text{Cu}]^3/[\text{Au}]^2[\text{Cu}^{2+}]^3$
 - $K = [\text{Cu}^{2+}]^3/[\text{Au}^{3+}]^2$
 - $K = [\text{Au}]^3[\text{Cu}^{2+}]^2/[\text{Au}^{3+}]^3[\text{Cu}]^2$
34. Within a period, what happens to the size of an atom as the atomic number increases?
- Size does not change.
 - The atom gets smaller.
 - The atom gets larger.
 - The atom breaks down.
 - There is no relationship.
35. Which one of the following is true when a small amount of acid is added to pure water and a buffered water solution?

<u>Pure water</u>	<u>Buffered water</u>
A. pH increases drastically	pH increases drastically
B. pH decreases drastically	pH decreases drastically
C. pH increases significantly	pH decreases significantly
D. pH remains nearly unchanged	pH remains nearly unchanged
E. pH decreases drastically	pH remains nearly unchanged

36. Suppose 0.10 moles of the compound AB_2 are dissolved in 1.0 kg of water. In this solution, AB_2 ionizes completely. Which of the following is the correct molality for A and B?

- A. The molality of A is 0.20 mol/kg and the molality of B is 0.10 mol/kg.
- B. The molality of A is 0.10 mol/kg and the molality of B is 0.20 mol/kg.
- C. The molality of A is 0.10 mol/kg and the molality of B is 0.10 mol/kg.
- D. The molality of A is 0.20 mol/kg and the molality of B is 0.20 mol/kg.
- E. The molality of A is 0.40 mol/kg and the molality of B is 0.20 mol/kg.

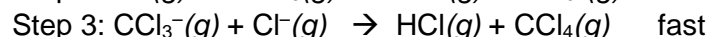
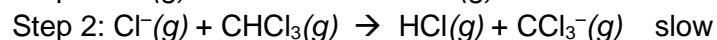
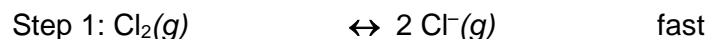
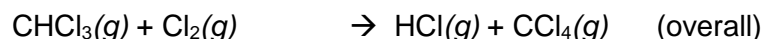
37. If the frequency of light required for moving an electron from a lower energy to a higher is $1.11 \times 10^{14} \text{ s}^{-1}$. What is the corresponding change in energy (ΔE)?

- A. $1.67 \times 10^{47} \text{ J}$
- B. $7.35 \times 10^{-20} \text{ J}$
- C. $7.40 \times 10^{-18} \text{ J}$
- D. $5.97 \times 10^{-48} \text{ J}$
- E. $1.67 \times 10^{27} \text{ J}$

38. A tank of gas is found in the coldest part of the refrigerator (at 0°C). It contains 1 mole of oxygen and 3 moles of neon gases. The volume of the tank is 11.2 L. What is the partial pressure of oxygen in the tank?

- A. 0.25 atm
- B. 0.15 atm
- C. 2.0 atm
- D. 8.0 atm
- E. 4.0 atm

39. In the proposed reaction mechanism below, which of the following is an intermediate?



- A. HCl
- B. CCl_3^-
- C. CCl_4
- D. CHCl_3
- E. Cl_2

40. A sample of argon gas occupies 3.8 L at 83°C and 4.25 atm. What will the new volume be if the conditions are changed to 52°C and 1.75 atm?

- A. 5.8 L
- B. 4.1 L
- C. 3.5 L
- D. 9.2 L
- E. 8.4 L