Science Olympiad

Eastside Invitational
Stevenson High School
2017

Chemistry Lab

Part 1 – Written Exam
Part 2 – Lab Component

Read the directions below. Do not start the test until you have been instructed to do so.

- You may write on this test.
- You may separate this test into multiple sections.
- Only answers recorded on the scantron will be graded.
- You will find reference pages at the beginning of the test that you may refer to at any point during the test or lab.
- All pages of this test must be stapled together and returned at the end of the testing period.

Team Number: _____

School/Team: _____

Student Names: _____

1																	18
1 **H** 1.008	2											13	14	15	16	17	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305	3	4	5	6	7	8	9	10	11	12	13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.630	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.95	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (265)	105 **Db** (268)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

* Lanthanide series	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
# Actinide series	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	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)

TABLE 10.3 van der Waals Constants for Gas Molecules

Substance	a (L^2-atm/mol^2)	b (L/mol)
He	0.0341	0.02370
Ne	0.211	0.0171
Ar	1.34	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0510
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
H_2O	5.46	0.0305
CH_4	2.25	0.0428
CO_2	3.59	0.0427
CCl_4	20.4	0.1383

Table 1.
Specific Heat of Water (J/g•°C)

Solid	2.1
Liquid	4.184
Gas	1.9

Table 2.
Latent Heat of Water/Phase Changes (kJ/mol)

ΔH_{fusion}	6.02
$\Delta H_{vaporization}$	40.7

RELATIVE DENSITY OF WATER

S. No.	Temperature (°C)	Relative density	S. No.	Temperature (°C)	Relative density
1	4	1.000000	22	25	0.997074
2	5	0.999992	23	26	0.996813
3	6	0.999968	24	27	0.996542
4	7	0.999930	25	28	0.996262
5	8	0.999876	26	29	0.995974
6	9	0.999809	27	30	0.995676
7	10	0.999728	28	31	0.995369
8	11	0.999633	29	32	0.995054
9	12	0.999525	30	33	0.994731
10	13	0.999404	31	34	0.994399
11	14	0.999271	32	35	0.994059
12	15	0.999127	33	36	0.993712
13	16	0.998970	34	37	0.993357
14	17	0.998802	35	38	0.992994
15	18	0.998623	36	39	0.992623
16	19	0.998433	37	40	0.992246
17	20	0.998232	38	41	0.99186
18	21	0.998021	39	42	0.99147
19	22	0.997799	40	43	0.99107
20	23	0.997567	41	44	0.99066
21	24	0.997326	42	45	0.99024

VAPOR PRESSURE OF WATER

T	P	T	P	T	P	T	P
°C	torr	°C	torr	°C	torr	°C	torr
19.1	16.581	22.1	19.948	25.1	23.897	28.1	28.514
19.2	16.685	22.2	20.070	25.2	24.039	28.2	28.680
19.3	16.789	22.3	20.193	25.3	24.182	28.3	28.847
19.4	16.894	22.4	20.316	25.4	24.326	28.4	29.015
19.5	16.999	22.5	20.440	25.5	24.471	28.5	29.184
19.6	17.105	22.6	20.565	25.6	24.617	28.6	29.354
19.7	17.212	22.7	20.690	25.7	24.764	28.7	29.525
19.8	17.319	22.8	20.815	25.8	24.912	28.8	29.697
19.9	17.427	22.9	20.941	25.9	25.060	28.9	29.870
20.0	17.535	23.0	21.068	26.0	25.209	29.0	30.043
20.1	17.644	23.1	21.196	26.1	25.359	29.1	30.217
20.2	17.753	23.2	21.324	26.2	25.509	29.2	30.392
20.3	17.863	23.3	21.453	26.3	25.660	29.3	30.568
20.4	17.974	23.4	21.583	26.4	25.812	29.4	30.745
20.5	18.085	23.5	21.714	26.5	25.964	29.5	30.923
20.6	18.197	23.6	21.845	26.6	26.117	29.6	31.102
20.7	18.309	23.7	21.977	26.7	26.271	29.7	31.281
20.8	18.422	23.8	22.110	26.8	26.426	29.8	31.461
20.9	18.536	23.9	22.243	26.9	26.582	29.9	31.642
21.0	18.650	24.0	22.377	27.0	26.739	30.0	31.824
21.1	18.765	24.1	22.512	27.1	27.897	30.1	32.007
21.2	18.880	24.2	22.648	27.2	27.055	30.2	32.191
21.3	18.996	24.3	22.785	27.3	27.214	30.3	32.376
21.4	19.113	24.4	22.922	27.4	27.374	30.4	32.561
21.5	19.231	24.5	23.060	27.5	27.535	30.5	32.747
21.6	19.349	24.6	23.198	27.6	27.696	30.6	32.934
21.7	19.468	24.7	23.337	27.7	27.858	30.7	33.122
21.8	19.587	24.8	23.476	27.8	28.021	30.8	33.312
21.9	19.707	24.9	23.616	27.9	28.185	30.9	33.503
22.0	19.827	25.0	23.756	28.0	28.349	31.0	33.695

Science Olympiad – Chemistry Lab

Part 1 – Written Test

Multiple Choice – Select the best answer for each below. Be sure to transfer your answers to the scantron.

1. Which of the following statements about gases is not true?
    a. Gases can be easily compressed
    b. The distance between gas molecules is large
    c. Gases can form homogenous mixtures
    d. Gases will expand to fill their container
    e. All gases are colorless and odorless under standard conditions
2. A gas sample at constant temperature has a volume of 250 mL and 3.50 atm. What volume will the sample occupy if the pressure is changed to 1.55 atm?
    a. 111 mL
    b. 217 mL
    c. 565 mL
    d. 1.36 L
    e. 5.65 L
3. A sealed balloon will break if its volume reaches 4.50 L. At 20°C, the volume of the balloon is 3.79 L. At what temperature will the balloon break if the pressure stays the same?
    a. 17°C
    b. 24°C
    c. 26°C
    d. 51°C
    e. 75°C
4. How many moles of a gas occupy 2.67 L at 2.3 atm and 25°C?
    a. 2.5×10^{-3} mol
    b. 0.030 mol
    c. 0.25 mol
    d. 3.0 mol
    e. 4.0 mol
5. Which of the following gases would have the highest average molecular speed at 25°C?
    a. O_2
    b. N_2
    c. CO_2
    d. CH_4
    e. SF_6
6. In the van der Waals equation, the constants "a" and "b" are
    a. Used to correct for the finite volume of gas molecules and the attractive forces between gas molecules
    b. Equal to each other for any real gas
    c. Used to correct for the difference between Celsius and Kelvin
    d. Equal to 1 for ideal gases
    e. Used to correct for the fact that collisions of gas molecules are not really completely elastic
7. The vapor pressure of a liquid will decrease if
    a. The volume of the vapor above the liquid is increased
    b. The volume of the liquid is decreased
    c. The temperature is decreased
    d. The surface area of the liquid is decreased
    e. A more volatile liquid is added

8. Which of the following statements is/are true?
   I. Deviations in the behavior of gases from the ideal-gas equation occur because gas molecules occupy a finite volume in a container
   II. Deviations in the behavior of gases from the ideal-gas equation occur because attractions between gas molecules exist
   III. Deviations in the behavior of gases from the ideal-gas equation decrease with increasing temperature
   a. I only
   b. II only
   c. I and II
   d. II and III
   e. I, II, and III

9. How much heat is required to convert 100 g of water at 40°C to water vapor at 100°C?
   a. 227 kJ
   b. 418 kJ
   c. 226 kJ
   d. 25.1 kJ
   e. 251 kJ

10. A chemist uses a cylinder with a piston and gas inlet valve. Consider the following change: Inject an additional gas through the gas inlet valve. What will be the consequences for the pressure of the gas and for the number of moles of gas present?
   a. The pressure of the gas will decrease, and the number of moles of gas present will decrease
   b. The pressure of the gas will increase, and the number of moles of gas present will increase
   c. The pressure of the gas will decrease, and the number of moles of gas present will increase
   d. There will be no changes in the pressure of the gas or in the number of moles
   e. The number of moles will stay the same, and the pressure of the gas will decrease

11. According to the ideal-gas equation, which of the following statements is true?
   a. If gases are mixed, the partial pressure of each lowers the partial pressure of the others
   b. For Boyle's law to apply, a gas must be kept at constant pressure
   c. The volume of a gas is not changed if it is heated from 0°C to 100°C and at the same volume if the pressure is increased from 750 torr to 850 torr
   d. The volume of a gas doubles when the centigrade temperature doubles if all other variables are held constant
   e. The volume of a gas decreases by a factor of 2 when the pressure is doubled if all other variables are held constant

12. At STP, 20. Microliters of O_2 contain 5.4×10^{16} molecules. How many molecules are in 20. microliters of N_2?
   a. 5.4×10^{15}
   b. 1.0×10^{16}
   c. 2.7×10^{16}
   d. 5.4×10^{16}

13. A blimp is filled with 5000. L of helium at 28.0°C and 99.7 kPa. What is the mass of helium used?
   a. 797 g
   b. 810. g
   c. 879 g
   d. 8.57×10^3 g

14. What is the density of nitrogen gas at STP?
   a. 0.62 g/L
   b. 1.14 g/L
   c. 1.25 g/L
   d. 2.03 g/L

15. Find the volume of methane that will produce 12 L of hydrogen in the reaction below. Assume temperature and pressure remain constant.
$CH_4(g) + H_2O(g) \rightarrow CO(g) + H_2(g)$
    a. 4.0 L
    b. 12 L
    c. 24 L
    d. 36 L

16. What is the partial pressure of oxygen, in torr, in the atmosphere when the atmospheric pressure is 760.0 torr?

Components of Air	*Mole Fraction*
Nitrogen	0.781
Oxygen	0.209
Argon	0.010

    a. 159
    b. 430
    c. 601
    d. 720
    e. 760

17. A gas is heated in a sealed container. Which of the following occur?
    a. Gas pressure rises
    b. Gas density decreases
    c. The average distance between molecules increases
    d. All of the above

18. A _____ ΔH corresponds to a _____ process. Select all that are true.
    a. Negative; endothermic
    b. Negative; exothermic
    c. Positive; exothermic
    d. Positive; endothermic
    e. Zero; exothermic

19. An amount of heat equal to 3500 J is released from a system. In addition, 1500 J of work is done by the system on the surroundings. What is the change in internal energy of the system?
    a. 1500 J
    b. 2000 J
    c. 3500 J
    d. 5000 J
    e. -5000 J

20. ΔH° for the reaction below is -482 kJ. Calculate the heat released when 12.0 g of CO(g) reacts completely, according to the following chemical equation:
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
    a. 2.89×10^3 kJ
    b. 206 kJ
    c. 103 kJ
    d. 65.7 kJ
    e. -482 kJ

21. What is the specific heat of iron if 13.5 J is required to raise the temperature of a 10-g sample by 3K?
    a. 0.45 J/g-K
    b. 2.22 J/g-K
    c. 4.05 J/g-K
    d. 45 J/g-K
    e. 405 J/g-K

22. For which of the species in the following chemical reaction is the enthalpy of formation equal to zero?

$2Co(s) + H_2(g) + 8PF_3(g) \rightarrow 2HCo(PF_3)_4(l)$

a. $Co(s)$
b. $H_2(g)$
c. $PF_3(g)$
d. $HCo(PF_3)_4(l)$
e. Both $Co(s)$ and $H_2(g)$

23. What is the standard heat of combustion of $CH_4(g)$? Use the following data:

Standard Heats of Formation	
$CH_4(g)$	-74.8 kJ/mol
$CO_2(g)$	-393.5 kJ/mol
$H_2O(l)$	-285.8 kJ/mol

a. -890.3 kJ/mol
b. -604.6 kJ/mol
c. -252.9 kJ/mol
d. -182.5 kJ/mol

24. 10.0 kJ of heat are added to one kilogram of iron at 10. °C. What is the final temperature of the iron? The specific heat of iron is 0.45 J/g-°C.
a. 22˚C
b. 27 ˚C
c. 32 ˚C
d. 37 ˚C

25. Ozone can be destroyed through reaction with
a. An oxygen radical
b. UV radiation
c. Nitrogen gas
d. Both a & b

26. Chlorofluorocarbons contribute to ozone depletion by
a. Releasing chlorine radicals
b. Directly reacting with ozone
c. Releasing fluorine radicals
d. Inhibiting the ability of ozone to migrate to areas of low concentration

27. Which of the following is not a common contributing reaction to ozone depletion?
a. $HO + O_3 \rightarrow HO_2 + O_2$
b. $NO + O_3 \rightarrow NO_2 + O_2$
c. $ClO + O \rightarrow Cl + O_2$
d. $PO_3 + O \rightarrow PO_2 + O_2$

28. CFC stands for
a. Chlorinated Freon compound
b. Chlorofluorocarbon
c. Carbonated fluorine compound
d. Caustic fluorine carbohydrate
e. Carbofluoro compound

29. The concentration of which greenhouse gas has increased steadily over the law few decades?
a. H_2O
b. CO
c. CO_2
d. H_2O_2
e. O_2

30. Cl atoms formed via photolysis of C-Cl bonds of CFC's in the stratosphere are particularly effective in destroying ozone at these altitudes because
    a. Cl atoms absorb UV, which generate O atoms to react with O_2 to produce ozone
    b. Cl atoms catalytically convert O_3 to O_2
    c. Cl atoms stoichiometrically convert O_3 to O_2
    d. Cl atoms react with H atoms, which catalyze conversion of O_2 to O_3
    e. Cl atoms react with N atoms, which catalyze conversion of O_2 to O_3

Completion – solve the following problems. Report your answers on the scantron form in the space provided. Be sure to include units and significant figures with your final answer.

31. A 4.22 g sample of copper (II) sulfide was added to excess hydrochloric acid, and the resulting hydrogen sulfide gas was collected over water. What volume of gas was collected at 30.5°C when the atmospheric pressure was 749 torr?

32. What is the heat change that takes place when 36.0 g of water at atmospheric pressure cools from 125°C to 40.°C?

Science Olympiad – Chemistry Lab

Part 2 - Lab Component

Background Information: In this lab you will combine two solutions that react in a 1:1 ratio in order to form a product. The stoichiometry of the reaction is as follows:

$$A + B \rightarrow C$$

Task Details: Use calorimetry to determine the enthalpy of reaction of the product, "C", in kJ/mol. Assume that the calorimeter is perfectly insulating, that the specific heat of the solution is 4.184 J/(g•°C), and that the density of the solution is 1.00 g/mL. Write your final answer in the box provided at the bottom of this page with the correct sign, significant figures, and units.

Materials List:

- Coffee-cup calorimeter (maximum volume of _____ mL)
- Thermometer
- Solution A (___ mL max.)
- Solution B (___ mL max.)
- Graduated Cylinder
- Distilled water

Disposal: All solutions can be disposed of in the sink with copious amounts of water.

Data: Clearly record all measurements below.

Calculations: Clearly show all calculations below.

Final Answer: