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CHEM 110 – Dr. McCorkle – Exam #3 ***KEY***

While you wait, please complete the following information:

Name: ________________________________

Student ID: ________________________________

Turn off cellphones and stow them away. No headphones, mp3 players, hats, sunglasses, food, drinks, restroom breaks, graphing calculators, programmable calculators, or sharing calculators. Grade corrections for incorrectly marked or incompletely erased answers will not be made.

Periodic Table of the Elements

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	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
4	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 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	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 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La * 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	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)
7	87 Fr (223)	88 Ra (226)	89 Ac ** (227)	104 Rf (267)	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 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

Lanthanide Series *	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 **	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)

Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]

1. In the kinetic molecular theory of gas behavior, the assumption is made that gas molecules
   A) occasionally come to rest.
   B) are attracted to each other by strong forces.
   C) are close together in their container.
   D) move with a kinetic energy equal to their centigrade temperature.
   E) move rapidly in random directions.

2. The atmospheric pressure in Denver, CO is 633 mmHg. What is this pressure in atm?
   A) 1.20 atm B) 633 atm **C) 0.833 atm** D) 1.00 atm E) 127 atm

3. The volume of a gas with a pressure of 1.2 atm increases from 1.0 L to 4.0 L. What is the final pressure of the gas, assuming no change in moles or temperature?
   A) 1.2 atm **B) 0.30 atm** C) 3.3 atm D) 4.8 atm E) 1.0 atm

4. Complete the following statement: In Charles's Law, the volume of a gas ________ when the ________ decreases.
   A) increases; temperature B) increases; quantity of gas
   C) increases; pressure **D) decreases; temperature**
   E) decreases; pressure

5. A gas at 5.00 atm pressure was stored in a tank during the winter at 5.0 °C. During the summer, the temperature in the storage area reached 40.0 °C. What was the pressure in the gas tank then?
   A) 0.625 atm B) 4.44 atm **C) 5.63 atm** D) 40.0 atm E) 69.5 atm

6. A mixture of 10.0 g of Ne and 10.0 g of Ar have a total pressure of 1.6 atm. What is the partial pressure of Ne?
   A) 0.40 atm B) 0.54 atm C) 0.80 atm **D) 1.1 atm** E) 1.3 atm

7. How many moles of neon occupy a volume of 14.3 L at STP?
   A) 36.7 moles B) 32.0 moles C) 6.45 moles **D) 0.638 moles** E) 1.57 moles

8. Calculate the root mean square velocity of nitrogen molecules at 25 °C.
   A) 149 m/s B) 297 m/s **C) 515 m/s** D) 729 m/s E) 1090 m/s

9. Define *energy*.
   A) the flow of energy caused by a chemical reaction
   B) the flow of energy caused by a temperature difference
   C) the result of a force acting through a distance
   D) the capacity to do work
   E) a chemical reaction

10. The gas in a piston (defined as the system) is warmed and absorbs 640. J of heat. The expansion performs 344 J of work on the surroundings. What is the change in internal energy for the system in joules?
    A) 296 J B) 984 J C) −296 J D) −984 J E) 1.86 J

11. Which is the correct equation for the formation of $Na_2CO_3(s)$ from its elements in their standard states?
    A) $2\ Na(s) + C(s, graphite) + 3\ O(g) \rightarrow Na_2CO_3(s)$
    B) $2\ Na(s) + C(s, graphite) + 3/2\ O_2(g) \rightarrow Na_2CO_3(s)$
    C) $2\ Na^+(aq) + CO_3^{2-}(aq) \rightarrow Na_2CO_3(s)$
    D) $4\ Na(s) + 2\ C(s, graphite) + 6\ O(g) \rightarrow 2\ Na_2CO_3(s)$
    E) $4\ Na(s) + 2\ C(s, graphite) + 3\ O_2(g) \rightarrow 2\ Na_2CO_3(s)$

Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. Place a box around your final answer.

12. A sample of nitrogen gas had a volume of 500. mL, a pressure in its closed container of 640. torr, and a temperature of 25 °C. What was the new volume of the gas in liters when the temperature was changed to 50 °C and the new pressure was 1.00 atm? [6 points]

$$P_1 = 640.\ \text{torr} \times \frac{1\ \text{atm}}{760\ \text{torr}} = 0.842\ \text{atm}$$

$$V_1 = 500.\ \text{mL} \times \frac{10^{-3}\ \text{L}}{1\ \text{mL}} = 0.500\ \text{L}$$

$T_1 = 25 + 273 = 298$ K

$P_2 = 1.00$ atm

$V_2 = ?$ L

$T_1 = 50 + 273 = 323$ K

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(0.842\ \text{atm})(0.500\ \text{L})(323\ \text{K})}{(298\ \text{K})(1.00\ \text{atm})} = 0.456\ \text{L}$$

13. A 0.334 g sample of an unknown halogen occupies 109 mL at 125 °C and 1.41 atm. What is the identity of the halogen? [5 points]

$$V = 109\ \text{mL} \times \frac{10^{-3}\ \text{L}}{1\ \text{mL}} = 0.109\ \text{L}$$

$T = 125 + 273 = 398$ K

$$n = \frac{PV}{RT} = \frac{(1.41\ \text{atm})(0.109\ \text{L})}{\left(0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(398\ \text{K})} = 4.7\underline{0}6 \times 10^{-3}\ \text{mol}$$

$$MM = \frac{0.334\ \text{g}}{4.7\underline{0}6 \times 10^{-3}\ \text{mol}} = 71.0\ \text{g/mol}$$

$F_2 = 38.00$ g/mol

$Cl_2 = 70.90$ g/mol → Must be Cl_2!

$Br_2 = 159.80$ g/mol

$I_2 = 253.80$ g/mol

14. Consider the following reaction:

$$2\ H_3PO_4(aq) + Al_2(CO_3)_3(s) \rightarrow 3\ H_2O(l) + 3\ CO_2(g) + 2\ AlPO_4(s)$$

When 35.0 g of $Al_2(CO_3)_3$ reacts, how many L of CO_2 gas are formed at 55 °C and a pressure of 975 mmHg? [5 points]

$$n_{CO_2} = 35.0\ g\ Al_2(CO_3)_3 \times \frac{1\ mol\ Al_2(CO_3)_3}{233.99\ g} \times \frac{3\ mol\ CO_2}{1\ mol\ Al_2(CO_3)_3}$$
$$= 0.44\underline{8}7\ mol$$
$$P_{CO_2} = 975\ mmHg \times \frac{1\ atm}{760\ torr} = 1.2\underline{8}3\ atm$$
$$T_{CO_2} = 55 + 273 = 328\ K$$

PV = nRT

$$V = \frac{nRT}{P} = \frac{(0.44\underline{8}7\ mol)\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(328\ K)}{1.2\underline{8}3\ atm} = 9.41\ L$$

15. A 4.98 g sample of aniline ($C_6H_5NH_2$) was combusted in a bomb calorimeter with a heat capacity of 4.25 kJ/°C. If the temperature rose from 29.5 °C to 69.8 °C, determine the value of ΔE_{rxn} for aniline. [4 points]

$$q_{cal} = C_{cal} \times \Delta T = \left(4.25\ \frac{kJ}{°C}\right) \times (69.8°C - 29.5°C) = 17\underline{1}.3\ kJ$$

$$4.98\ g \times \frac{1\ mol\ C_6H_5NH_2}{93.14\ g} = 0.053\underline{4}7\ mol$$

$$q_{rxn} = -q_{cal}$$

$$\Delta E_{rxn} = \frac{q_{rxn}}{mol} = \frac{-17\underline{1}.3\ kJ}{0.053\underline{4}7\ mol} = -3.20 \times 10^3\ kJ/mol$$

16. What volume in mL of benzene (C_6H_6, d = 0.88 g/mL) is required to produce 1.5×10^3 kJ of heat according to the following reaction: [4 points]

$$2\ C_6H_6(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(l) \qquad \Delta H^\circ_{rxn} = -6278\ \text{kJ}$$

$$\mathbf{1.5 \times 10^3\ kJ \times \frac{2\ mol\ C_6H_6}{6278\ kJ} \times \frac{78.12\ g}{1\ mol\ C_6H_6} \times \frac{1\ mL}{0.88\ g} = 42\ mL}$$

17. A piece of iron (mass = 25.0 g) at 125 °C is placed in a Styrofoam coffee cup containing 25.0 mL of water at 20. °C. Assuming that no heat is lost to the cup or the surroundings, what will the final temperature of the water be? (d_{water} = 0.997 g/mL, s_{Fe} = 0.449 J/g•°C, s_{water} = 4.184 J/g•°C) [5 points]

$\boldsymbol{q_{Fe} = -q_{water}}$

$\mathbf{m_{Fe} \times s_{Fe} \times \Delta T_{Fe} = -m_{water} \times s_{water} \times \Delta T_{water}}$

$\mathbf{m_{water}}$ **= 25.0 mL × 0.997 g/mL = 24.9 g**

25.0 g × 0.449 J/g·°C × ($\mathbf{T_f}$ – 125 °C) = −24.9 g × 4.184 J/g·°C × ($\mathbf{T_f}$ – 20. °C)

$\mathbf{T_f}$ **= 30.2 °C**

18. Calculate ΔH_{rxn} for the following reaction: [4 points]

$$2\ Sr(s) + O_2(g) \rightarrow 2\ SrO(s)$$

Use the following reactions and given ΔH′s.

$SrO(s) + CO_2(g) \rightarrow SrCO_3(s)$	$\Delta H = -234$ kJ
$C(s, graphite) + O_2(g) \rightarrow CO_2(g)$	$\Delta H = -394$ kJ
$2\ SrCO_3(s) \rightarrow 2\ Sr(s) + 2\ C(s, graphite) + 3\ O_2(g)$	$\Delta H = +2440$ kJ

Reverse #3
$2\ Sr(s) + \cancel{2\ C(s, graphite)} + \cancel{3}\ O_2(g) \rightarrow \cancel{2\ SrCO_3(s)}$ **$\Delta H = -2440$ kJ**

Reverse #2 and double it
$\cancel{2\ CO_2(g)} \rightarrow \cancel{2\ C(s, graphite)} + \cancel{2\ O_2(g)}$ **$\Delta H = +788$ kJ**

Reverse #1 and double it
$\cancel{2\ SrCO_3(s)} \rightarrow 2\ SrO(s) + \cancel{2\ CO_2(g)}$ **$\Delta H = +468$ kJ**

$2\ Sr(s) + O_2(g) \rightarrow 2\ SrO(s)$ **$\Delta H = -1184$ kJ**

19. Calculate ΔH°_f of $SO_2(g)$ using the following reaction and standard enthalpies of formation: [5 points]

$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(l) + 2\ SO_2(g) \qquad \Delta H^\circ_{rxn} = -1124 \text{ kJ}$$

$\Delta H^\circ_{rxn} = \Sigma[n\ \Delta H_f^\circ(\text{products})] - \Sigma[n\ \Delta H_f^\circ(\text{reactants})]$

$-1124 \text{ kJ} = [2(-285.8) + 2\Delta H_f^\circ(SO_2)] - [2(-20.6) + 3(0)]$

$\Delta H_f^\circ(SO_2) = -296.8$ kJ/mol

20. Acetylene gas (C_2H_2) is commonly used in welding torches. When burned with pure oxygen, instead of air, it burns at about 3,500 °C!

a. Write a balanced equation for the combustion of acetylene (C_2H_2) in pure oxygen. (Products are gaseous due to the high temperature.) [2 points]

$2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(g)$

b. Calculate the ΔH°_{rxn} using the standard enthalpies of formation. [4 points]

$\Delta H^\circ_{rxn} = \Sigma[n\ \Delta H_f^\circ(\text{products})] - \Sigma[n\ \Delta H_f^\circ(\text{reactants})]$

$\Delta H^\circ_{rxn} = [4(-393.5) + 2(-241.8)] - [2(+227.4) + 5(0)] = -2512.4\ \text{kJ}$

c. Two pieces of iron at 23 °C have a total mass of 1250 g. What is the final temperature of the iron in Celsius if 25.5 g of acetylene is used to weld them together? Assume all of the heat from the combustion of acetylene is transferred to the iron. (s_{Fe} = 0.449 J/g·°C) [6 points]

$$25.5\ \text{g}\ C_2H_2 \times \frac{1\ \text{mol}\ C_2H_2}{26.04\ \text{g}} \times \frac{-2512.4\ \text{kJ}}{2\ \text{mol}\ C_2H_2} \times \frac{10^3\ \text{J}}{1\ \text{kJ}} = -1.23 \times 10^6\ \text{J}$$

$q_{Fe} = -q_{C2H2} = 1.23\times10^6$ J

$q_{Fe} = m_{Fe} \times s_{Fe} \times \Delta T_{Fe}$

1.23×10^6 J = 1250 g × 0.449 J/g·°C × (T_f – 23 °C)

T_f = 2215 °C

21. The tiles on the space shuttle have an incredible specific heat capacity of 62.8 J/g·°C and were designed to withstand incredible temperatures. Let's imagine that after a successful mission, the space shuttle reenters Earth's atmosphere where its external temperature rises from −157 °C to 1650 °C generating 5.38×10^{11} J of heat. If the average mass of each tile is 195 g, how many tiles would you need to absorb this heat? (Assume the heat is distributed evenly among the tiles.) [5 points]

q = m × C × ΔT

$$\mathbf{m = \frac{q}{C \times \Delta T}}$$

$$\mathbf{m = \frac{5.38 \times 10^{11}\ J}{62.8\ \frac{J}{g \cdot {}^\circ C} \times \ (1650^\circ C - \ -157^\circ C)}}$$

$$\mathbf{m = \frac{5.38 \times 10^{11}\ J}{62.8\ \frac{J}{g \cdot {}^\circ C} \times \ (1807^\circ C)} = 4.7\underline{4}09 \times 10^{6}\ g}$$

$$\mathbf{m\ = 4.7\underline{4}09 \times 10^{6}\ g \ \times \frac{1\ tile}{195\ g} = \ 24{,}312.5\ tiles = 2.43 \times 10^{4}\ tiles}$$

Extra Credit: What Italian scientist invented the barometer? [2 points]

Torricelli (the *torr* is named in his honor)

Formulas & Constants
(you may or may not need)

1 inch = 2.54 cm (exact)	1 mile = 5280 ft ≈ 1.609 km	1 kg ≈ 2.205 lb
1 lb = 16 oz ≈ 453.6 g	1 gal = 4 qt = 8 pt ≈ 3.785 L	1 L = 1000 cm^3
K = °C + 273.15	°F = 1.8 x °C + 32	°C = (°F – 32)/1.8
1 cal = 4.184 J	1 Cal = 1000 cal	q = m x C x ΔT
Avogadro's # = 6.022×10^{23}	Molar volume = 22.4 L	$R = 0.08206 \frac{\text{L·atm}}{\text{mol·K}}$
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$	$KE = \frac{1}{2}mv^2 = \frac{3}{2}RT$
1 atm = 760 mmHg	1 mmHg = 1 torr	$P_{Total} = P_1 + P_2 + \ldots$
$P_A = X_A \cdot P_{Total}$	PV = nRT	ΔE = q + w
w = −PΔV	q = C × ΔT	q = m × s × ΔT
$\Delta H°_{rxn} = \Sigma[n\ \Delta H_f°(\text{products})] - \Sigma[n\ \Delta H_f°(\text{reactants})]$		R = 8.314 J/mol·K

Standard Enthalpies of Formation at 25 °C

Substance	$\Delta H°_f$ (kJ/mol)
$CH_4(g)$	−74.9
$C_2H_2(g)$	+227.4
$C_6H_6(l)$	+49.1
$CO_2(aq)$	−413.8
$CO_2(g)$	−393.5
$H_2O(g)$	−241.8
$H_2O(l)$	−285.8
$H_2S(aq)$	−39.4
$H_2S(g)$	−20.6

Scratch Page

(to be handed in)