University of Louisville **Chem 201 Exam 3 Dr. Hoyt** **Fall 2014**

name KEY

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1. The following thermochemical equations are provided. Circle the correct answer for each question. *Note: all of the problems on this page are independent of each other; your answer to one problem does not depend on having a previous problem correct. Use your periodic table for scratch paper; raise your hand if you need more scratch paper.*

Eq. 1 $2\ O_3\ (g) \rightarrow 3\ O_2\ (g)$ $\Delta H^\circ_{rxn} = -427$ kJ/mol

Eq. 2 $O_2\ (g) \rightarrow 2\ O\ (g)$ $\Delta H^\circ_{rxn} = +495$ kJ/mol

Eq.3 $NO\ (g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g)$ $\Delta H^\circ_{rxn} = -199$ kJ/mol

a. [2 pts] How much energy, in kJ, is required to break the O=O bond in one mole of O_2? ← = Eq. 2

②

+661 $\boxed{+495}$ +466 +427 +248 +233 +214 +199 +131

−661 −495 −466 −427 −248 −233 −214 −199 −131

b. [4 pts] Calculate the ΔH°_{rxn}, in kJ/mol, for $NO\ (g) + O\ (g) \rightarrow NO_2\ (g)$

+661 +495 +466 +427 +248 +233 +214 +199 +131

−661 −495 −466 −427 −248 $\boxed{-233}$ −214 −199 −131

④

Eq. 3: $NO + O_3 \rightarrow NO + O_2$ −199

reverse & $\frac{1}{2}$Eq 1: $\frac{3}{2}O_2 \rightarrow O_3$ +214

reverse & $\frac{1}{2}$Eq 2: $O \rightarrow \frac{1}{2}O_2$ −248

$NO + O \rightarrow NO_2$ −233

c. [3 pts] Stoichiometric amounts of NO and O are combined in a 5.2-liter container at room temperature and allowed to react: $NO\ (g) + O\ (g) \rightarrow NO_2\ (g)$. Before the reaction, the total pressure in the container is 0.048 atm. What is the pressure, in atm, after the reaction is complete and the product mixture has returned to room temperature? 2 mol → 1 mol complete rxn gives half the moles, so at same V & T ⇒ half the pressure

0.016 $\boxed{0.024}$③ 0.026 0.048 0.052 0.0821 0.096 0.25 1.0 1.6

2.4 2.6 4.8 5.2 9.6 10.4 11.2 14.4 22.4

$\frac{P_1}{n_1} = \frac{P_2}{n_2}$

NO 14.01
16.00
30.01 g/mol

$5.52\,g \times \frac{mol}{30.01\,g} = 0.1839\,mol$

d. [4 pts] What volume, in L, would be occupied by 5.52 g of NO at 24°C and 752 mm Hg (the approximate temperature and pressure in this room)?

24°C → 297 K

752 mm Hg → 0.9895 atm

0.000482 ② 0.00596 ③ 0.00735 0.0145 0.221 0.366 ③ 0.454

4.06 4.44 ② $\boxed{4.53}$④ 5.52 0.989 22.4 124 136 ②

$V = \frac{nRT}{P} = \frac{(0.1839\,mol)(0.08206\,L\cdot atm/K\cdot mol)(297\,K)}{0.9895\,atm} = 4.53\,L$

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2. [18 pts, 2 each] Supply an appropriate example of each of the following. In some cases there could be more than one acceptable answer; pick one.

In, Sn, Sb, Te, I, Xe An element with valence electrons in the 5p sublevel. ① any element after In

$H_2(g)$ (+ many others) A substance that has a ΔH^0_f of 0. (Include appropriate phase label.) ① ① ① $H^+_{(aq)}$

{Noble gases as $X_{(g)}$
H_2, N_2, O_2, F_2, Cl_2 (g)
$B_2(s)$ or (l), $I_2(s)$
Other elements $X_{(s)}$} ②

0 or 1 An allowed value of *ℓ* for an electron in the n=2 level.

He_g (or any Group 18) An element that exists under standard conditions as **individual gas-phase atoms.**

B A neutral atom with 3 valence electrons. ② any Group 3 or Group 13 ① Li

N A neutral atom with 3 unpaired electrons. ② any Group 5 or Group 9 or Group 15 ① Li

2 The total number of electrons in a filled 7g **orbital**. ① 18

Cs The Period 6 element with the largest atomic radius. ① any Period 6 element

He (+ many others) A neutral atom that is diamagnetic. ② any element in Group 2, 10, 18

3. [16 pts, 2 each] **Clearly** indicate whether each statement is TRUE or FALSE. If we can't tell which you mean, it's wrong.

false An electron relaxing from n=2 to n=1 ~~absorbs~~ a photon.

false The longer the wavelength of a photon, the ~~greater~~ its energy.

false One mole of an ideal gas occupies 22.4 L of volume, ~~regardless of conditions.~~ at STP

false The ideal gas law works best when gas molecules are relatively ~~close together.~~ dispersed

false The majority of elements in the periodic table are ~~diamagnetic~~ as neutral atoms.

true The 4d sublevel has a capacity of 10 electrons. ↑↓ ↑↓ ↑↓ ↑↓ ↑↓

true Main-group elements often form ions with noble-gas electron configurations.

true In an exothermic reaction, energy flows from a system into the surroundings.

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4. a. [3 pts] Give a ground-state valence orbital diagram (or “box diagram”) for an atom of silicon. (Write your answer in the box.)

a. $\overbrace{Si:\ [Ne]}^{optional}$ $\underset{3s}{\uparrow\downarrow}$ $\underset{3p}{\uparrow\ \uparrow\ \_}$ ②: $[Ne]3s^2 3p^2$

b. [3 pts] Give the ground-state, condensed electron configuration for an iron(II) ion. (Write your answer in the box.) Fe^{2+}

b. $\overbrace{Fe^{2+}:}^{optional}$ $[Ar]$ $\overbrace{4s^0}^{optional}$ $3d^6$

② $4s^2 3d^4$ ② $\underset{4s}{\_}$ $\underset{3d}{\uparrow\downarrow\ \uparrow\ \uparrow\ \uparrow\ \uparrow}$

② $4s^2 3d^6$

5. [12 pts, 2 each] Consider two 1-L samples of gas: one is O_2 and the other is H_2. Both are at 1 atm and 25 °C. Circle your choice for each of the following quantities or values. same T → same KE

a. greater average kinetic energy of molecules: O_2 H_2 [✓ both the same]

b. greater number of gas particles: O_2 H_2 [✓ both the same] same V, P, T → same n

c. faster average molecular speed: O_2 [✓ H_2] both the same lighter particles move faster for same T

d. greater mass: same n, heavier gas has more mass [✓ O_2] H_2 both the same

e. greater time required for a given fraction of molecules to effuse: = slower effusion [✓ O_2] H_2 both the same

f. higher density: greater mass, same volume ⇒ greater density [✓ O_2] H_2 both the same

6. [18 pts, 2 each] For each of the following, select the **greatest** value and circle your choice.

a. radius: [✓ Fe] Fe^{2+} Fe^{3+} all the same

b. number of orbitals: in 5s sublevel^1 [✓ in 3d sublevel^5] in 4p sublevel^3 all the same

c. energy of photon of light: orange blue [✓ UV] all the same

d. number of valence electrons: same group O Se [✓ both the same]

e. atomic size: C O [✓ Be] all the same

f. ionic radius: [✓ N^{3-}] O^{2-} F^- all the same

g. number of unpaired electrons: N^{3-} O^{2-} F^- [✓ all the same]

h. first ionization energy: Cl [✓ Ar] Na all the same

i. second ionization energy: [✓ Na] Mg Al all the same

for Na, 2nd IE comes from n=2

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7. (a) [4 pts] An x-ray has a wavelength of 1.3 Å. Calculate the energy (in J) of one photon of this radiation. (1 Å = 10^{-10} m)

① 8.6×10^{-44} J	③ 1.5×10^{-35} J	1.5×10^{-31} J	② 1.5×10^{-25} J
1.3×10^{-25} J	8.6×10^{-24} J	2.3×10^{-18} J	8.6×10^{-15} J
④ $\boxed{1.5 \times 10^{-15}\text{ J}}$	1.3×10^{-10} J	2.3×10^{-8} J	2.3×10^{8} J
1.3×10^{10} J	2.3×10^{18} J ②	1.5×10^{53} J	

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(3.00 \times 10^{8}\ \text{m/s})}{1.3 \times 10^{-10}\ \text{m}}$$

$$= 1.53 \times 10^{-15}\ \text{J}$$

8. The ΔH°_f values for various nitrogen species are given below. Answer each question appropriately.

ΔH°_f values: NH_4^+ (aq), –132.5 kJ NO_3^- (aq), –205.0 kJ NH_4NO_3 (s), –364.5 kJ N_2O (g), +82.1 kJ

a. [4 pts] Write the **reaction equation** corresponding to the ΔH°_f of solid ammonium nitrate. (Appropriate phase **labels** are required for credit.)

↳ formation of 1 mol from elements in stable states

$$\overset{①}{N_2(g)} + \overset{①}{2H_2(g)} + \overset{①}{\tfrac{3}{2}O_2(g)} \longrightarrow \overset{①}{NH_4NO_3(s)}$$

for each, formula and phase label must be correct to earn credit.

(-1) if coefficient other than 1 on NH_4NO_3

(-1) if not balanced

up to ③ if reversed. up to ② for $\boxed{NH_4^+(aq) + NO_3^-(aq) \rightarrow NH_4NO_3(s)}$

b. [4 pts] Calculate the ΔH_{rxn} for dissolving 1 mol of ammonium nitrate in water, and circle the correct value.

$$\underset{-364.5\text{ kJ}}{NH_4NO_3\text{ (s)}} \rightarrow \underset{-132.5\text{ kJ}}{NH_4^+\text{ (aq)}} + \underset{-205.0\text{ kJ}}{NO_3^-\text{ (aq)}} \qquad \Delta H_{rxn} = ?$$

$$\Delta H_{rxn} = \sum(\Delta H^\circ_f\text{ products}) - \sum(\Delta H^\circ_f\text{ reactants})$$

–702.0 kJ	–364.5 kJ	–337.5 kJ	–205.0 kJ	–132.5 kJ
–27.0 kJ ③	0 kJ	$\boxed{+27.0\text{ kJ}}$ ④	+132.5 kJ	+205.0 kJ
+337.5 kJ	+364.5 kJ	+702.0 kJ		

c. [2 pts] Based on your answer to (b), when ammonium nitrate dissolves in water, will the solution become warmer or cooler to the touch?

if any (–) answer above, warmer

if any (+) answer above, cooler

d. Ammonium nitrate can be used as an explosive; it was used in the bombing of the Oklahoma City Federal Building and in the first World Trade Center bombing, in 1993. The relevant reaction is:

$$NH_4NO_3\text{ (s)} \rightarrow N_2O\text{ (g)} + 2\,H_2O\text{ (g)} \qquad \Delta H_{rxn} = -37.0\text{ kJ}$$

[4 pts] How much heat is released when 25.0 g of ammonium nitrate decomposes according to the reaction shown? Circle the correct answer.

$$25.0\text{ g} \times \frac{\text{mol}}{80.05\text{ g}} \times \frac{37.0\text{ kJ}}{\text{mol}} = 11.6\text{ kJ}$$

NH_4NO_3:

14.01 × 2 = 28.02

1.008 × 4 = 4.032

16.00 × 3 = 48.00

80.05 g/mol

0 kJ	$\boxed{11.6\text{ kJ}}$ ④	25.0 kJ	37.0 kJ	82.1 kJ	114 kJ
241.8 kJ	365 kJ	740. kJ	925 kJ ②	74000 kJ	