F'08 Midterm Examination – Grading Key

PART A: Multiple Choice Section [2 points each]

For each question, circle the letter of the one correct answer and enter the answer on the Test Scoring Sheet **in pencil only**. The Test Scoring Answer Sheet will be considered final. There is no penalty for incorrect answers. Answers must be transferred to the Test Scoring Answer Sheet **within** the time given for the examination.

1. Which of the following statements is (are) true?

   I. An excited atom can return to a **higher** energy level by emitting light energy. ✗

   II. An atom can be excited to a higher energy level by absorption of light energy.

   III. The frequency and wavelength of light are inversely proportional.

   A) I. only B) II. only C) I. & III. only **(D) II. & III. only** E) I., II. & III.

2. Phenolphthalein is a commonly used acid/base indicator that appears bright pink in basic solution. The frequency of maximum absorbance in basic solution is 5.45×10^{14} s^{-1}. Calculate the energy, in kJ/mol, of photons corresponding to this frequency?

   (A) 217 kJ/mol
   B) 2.17×10^{-7} kJ/mol
   C) 3.62×10^{-19} kJ/mol
   D) 7.33×10^{-25} kJ/mol
   E) 6.00×10^{-43} kJ/mol

   $E = \varepsilon \times N_A = h\nu \times N_A$

   $E = 6.626 \times 10^{-34}\ J\cdot s \times 5.45\times10^{14}\ s^{-1} \times 6.022 \times 10^{23}\ mol^{-1}$

   $E = 2.175 \times 10^{5}\ J\cdot mol^{-1} \times 1\ kJ/1000\ J$

   $E = 217\ kJ\ mol^{-1}$

3. Which of the following represents a possible set of quantum numbers for an electron in an atom?

   A) $n = 3, l = 2, m_\ell = 0, m_s = \mathbf{0}$ ✗
   B) $n = 3, l = \mathbf{3}, m_\ell = -1, m_s = -½$ ✗
   C) $n = 3, l = 0, m_\ell = \mathbf{1}, m_s = -½$ ✗
   D) $n = 3, l = 0, m_\ell = \mathbf{1}, m_s = ½$ ✗
   (E) $n = 3, l = 2, m_\ell = -2, m_s = -½$

4. What is the ground-state electron configuration of Co^{2+}?

   A) $[Ar]\ 3d^7 4s^2$
   B) $[Ar]\ 3d^6 4s^1$
   (C) $[Ar]\ 3d^7$
   D) $[Ar]\ 3d^5 4s^2$
   E) $[Ar]\ 3d^9 4s^2$

   Z for Co = 27

   From periodic table: $[Ar]\ 4s^2 3d^7$

   Ground state for Co: $[Ar]\ 3d^7 4s^2$

   To create cation, remove two outermost electrons, i.e.,

   Ground state Co^{2+}: $[Ar]\ 3d^7$

5. How many unpaired electrons are in an atom of Fe?

A) 1
B) 2
C) 3
(D) 4
E) none of the these

Z for Fe = 26

From periodic table: [Ar] $4s^2 3d^6$

Ground state for Fe: [Ar] $3d^6 4s^2$

Energy Diagram: 4s ↑↓

3d: ↑↓ ↑ ↑ ↑ ↑

6. For the elements Be, B, N, and O, the first ionization energy increases in the order

A) Be < O < B < N
B) Be < B < N < O
(C) B < Be < O < N
D) B < Be < N < O
E) Be < B < O < N

I.E., in general, increases across a period, but exceptions exist because of electron configurations, i.e., B < Be because removing the second s electron > one p electron from B & O< N because removing the third p electron > fourth p electron.

7. Arrange O^{2-}, Br^-, and Mg^{2+} in order of increasing ionic radii.

A) $Mg^{2+} < Br^- < O^{2-}$
B) $Br^- < O^{2-} < Mg^{2+}$
C) $Br^- < Mg^{2+} < O^{2-}$
D) $O^{2-} < Br^- < Mg^{2+}$
(E) $Mg^{2+} < O^{2-} < Br^-$

O^{2-}: V = 10 e^-; Br^-: V = 36 e^-; Mg^{2+}: V = 10 e^-;

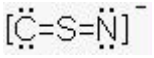
O^{2-} & Mg^{2+} are isoelectronic and ∴ $Mg^{2+} < O^{2-}$. (cations < anions)

Br^- has many more electrons and is therefore the largest.

8. The species **NOT** isoelectronic with N_2 is:

A) CO — V = 4 + 6 = 10 e^-
(B) NO — V = 5 + 6 = 11 e^-
C) CN^- — V = 4 + 5 + 1 = 10 e^-
D) C_2^{2-} — V = (2×4) + 2 = 10 e^-
E) NO^+ — V = 4 + 6 = 10 e^-

9. For the following Lewis structure, the formal charges on C, S, and N, respectively, are



C: 4 – 6 = –2; S: 6 – 4 = +2; N: 5 – 6 = –1

A) –1, +1, –1
(B) –2, +2, –1
C) –1, +2, –2
D) –2, +1, 0
E) 0, 0, –1

10. How many sigma and how many pi bonds are present in H_2CCHCN?

(A) 6 sigma and 3 pi
B) 6 sigma and 1 pi
C) 6 sigma and 2 pi
D) 7 sigma and 2pi
E) 9 sigma and 1pi

V = 1+1+4+4+1+4+5 = 20 electrons

H – C = C – C≡N:
  H H

Each bonding site contains one σ bond; double bond = σ + π; triple = σ + 2π.

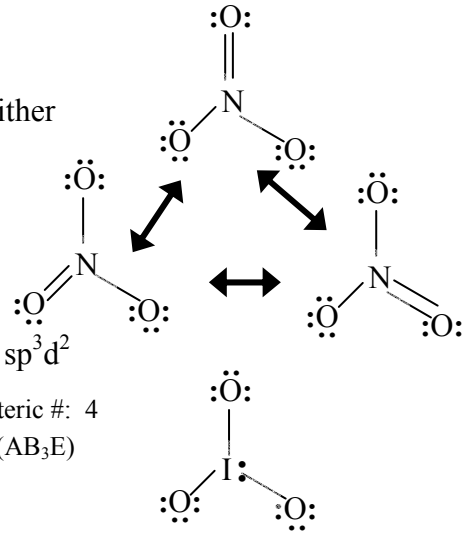
11. For NO_3^- and N_3^-, resonance forms can be written for

A) NO_3^- only B) N_3^- only (C) Both D) Neither

For NO_3^-, V = 5 + 3(6) + 1 = 24 electrons

For N_3^-, V = (3×5)+1 = 16 electrons

$:\ddot{N}–N\equiv N: \leftrightarrow :N=N=\ddot{N}: \leftrightarrow :N\equiv N–\ddot{N}:$



12. What type of hybrid orbital is used by iodine in IO_3^-?

A) sp B) sp^2 (C) sp^3 D) sp^3d E) sp^3d^2

V = 7 + (3 × 6) + 1 = 26 electrons

Steric #: 4

(AB_3E)

13. How many hydrogen atoms are in 1.0 mole of $(NH_4)_2HPO_4$?

A) 6.0×10^{23}

B) 2.4×10^{24}

C) 3.0×10^{24}

D) 4.8×10^{24}

(E) 5.4×10^{24}

1.0 mol = $6.0_2\times10^{23}$ $(NH_4)_2HPO_4$

In $(NH_4)_2HPO_4$ there are 9 H's

$\therefore 6.0_2\times10^{23}$ $(NH_4)_2HPO_4 \times \frac{9\text{ H atoms}}{1\text{ mol }(NH_4)_2HPO_4} = 5.4_2\times10^{24}$ H atoms

14. How many moles of K^+ ions are present in 2.00L of a 0.311 M solution of K_3PO_4?

A) 0.156 mol

B) 0.311 mol

C) 0.467 mol

D) 0.622 mol

(E) 1.87 mol

mol K_3PO_4 = 2.00 L × 0.311 mol/L = 0.622 moles K_3PO_4

mol K^+ = 0.622 moles K_3PO_4 × 3 mol K^+/1 mol K_3PO_4 = 1.87 mol K^+

15. If 0.01 moles hydrochloric acid, HCl, is completely neutralised with 0.250 M $Sr(OH)_2$, how many mL of strontium hydroxide is required?

(A) 20 mL

B) 25 mL

C) 40 mL

D) 50 mL

E) 80 mL

Rxn: $2HCl_{(aq)} + Sr(OH)_{2(aq)} \rightarrow SrCl_{2(aq)} + 2H_2O_{(l)}$

0.01 mol 0.250 mol/L

mol $Sr(OH)_2$ = 0.01 mol HCl × 1 mol $Sr(OH)_2$/2 mol HCl = 0.005 moles $Sr(OH)_2$

0.005 moles $Sr(OH)_2$ × 1 L/0.250 moles = 0.02 L × 1000 mL/1L = 20 mL

16. Consider the reaction: $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$

The volume of $O_2(g)$ produced at 25.0°C and 101.325 kPa when 1.25×10^{-3} moles of $KClO_3(s)$ react is:

A) 0.00256 L

(B) 0.0459 L

C) 0.0306 L

D) 0.0918 L

E) 0.0687 L

1.25×10^{-3} moles of $KClO_3 \times \frac{1\text{ mole }O_2}{2\text{ mol }KClO_3} = 1.87_5\times10^{-3}$ moles of O_2

$V = nRT/P = \frac{1.87_5\times10^{-3}\text{ moles of }O_2 \times 8.314\text{ kPa L/K mol} \times (25.0 + 273.15\text{K})}{101.325\text{ kPa}}$

V = 0.0459 L

17. Consider the following reactions for the determination of dissolved oxygen in water.

$2Mn^{2+}(aq) + 4OH^-(aq) + O_2(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)$

$MnO_2(s) + 4H_3O^+(aq) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 6H_2O(l)$

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

If 2.16×10^{-4} moles of $Na_2S_2O_3(aq)$ are used in the analysis, how many moles of dissolved oxygen were determined?

A) 2.16×10^{-4} mol
B) 2.70×10^{-5} mol
C) 1.08×10^{-4} mol
(D) 5.40×10^{-5} mol
E) 4.32×10^{-4} mol

$$2.16 \times 10^{-4} \text{ moles of } S_2O_3^{2-} \times \frac{1 \text{ mol } I_2}{2 \text{ mol } S_2O_3^{2-}} \times \frac{1 \text{ mol } MnO_2}{1 \text{ mol } I_2} \times \frac{1 \text{ mole } O_2}{2 \text{ mol } MnO_2}$$

$$= 5.40 \times 10^{-5} \text{ moles of } O_2$$

18. The equilibrium constant for the reaction $2H_2O(g) + 2Cl_2(g) \leftrightarrow 4HCl(g) + O_2(g)$ is 0.21 at a certain temperature. If 0.15 moles of H_2O, Cl_2, HCl and O_2 are mixed in a 1.00 L container at this temperature, which one of the following is true?

A) $Q_c < K_c$ and the reaction proceeds to the left.
(B) $Q_c < K_c$ and the reaction proceeds to the right.
C) $Q_c > K_c$ and the reaction proceeds to the left.
D) $Q_c > K_c$ and the reaction proceeds to the right.
E) $Q_c = K_c$ and the system is at equilibrium.

$$Q = \frac{[HCl]^4[O_2]}{[H_2O]^2[Cl_2]^2} = \frac{(0.15)^4(0.15)}{(0.15)^2(0.15)^2} = 0.15$$

Q < K, therefore too few products.

Reaction moves to right.

19. The conjugate acid of N_2H_4 is

(A) $N_2H_5^+$
B) N_2H_3
C) H_3O^+
D) $N_2H_3^-$
E) N_2H_5

$N_2H_4 + H^+ \rightarrow N_2H_5^+$

base conjugate acid

20. The pH of a 0.025 M aqueous solution of barium hydroxide is

A) 1.30
B) 1.60
C) 1.90
D) 12.40
(E) 12.70

	$Ba(OH)_2$	$\rightarrow$ Ba^{2+}	+ $2OH^-$
Initial	0.025 M	0	0
Change:	– 0.025 M	+0.025 M	+(2 ×0.025 M)
End	0	0.025 M	0.050 M

pOH = - log (0.050 M) = 1.30

pH = 14.00 – pOH = 12.70

Part B. [Total of 20 points]

1. Write the balanced net ionic equation for any reaction that occurs when the following aqueous solutions are mixed. Clearly identify your final answer. If no reaction occurs, write **no reaction**.

(i) calcium sulphate and iron (II) perchlorate: (**2 pts**)

-1 for each mistake

States must be included.

NIE: $CaSO_4(s) \rightarrow Ca^{2+}(aq) + SO_4^{2-}(aq)$

(ii) acetic acid and lithium hydroxide: (**2 pts**)

NIE: $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$

2. Rxn: $6Na(l) + Al_2O_3(s) \rightarrow 2Al(l) + 3Na_2O(s)$ (Given: MM (Al_2O_3) = 101.96 g/mol)

If 54.0 g of Al_2O_3 and 25.6 mL of liquid sodium (density = 0.781 g/mL) were reacted, 4.37 g of aluminum is isolated. Identify the limiting reagent and the percent yield of aluminum. **Show your work**.

Al_2O_3 Analysis:

54.0 g × 1 mol/101.96 g
= **0.529_6 mol Al_2O_3** (**1 pt**)

0.529_6 mol Al_2O_3 × **2** mol Al/**1** mol Al_2O_3
= **1.05_9 mol Al** (**1 pt**)

(1.05_9 mol Al × 26.98 g/1 mol
= 28.5_7 g Al)

Na Analysis:

25.6 mL × 0.781 g/1 mL = **19.9_9 g Na** (**1 pt**)

19.9_9 g Na × 1 mol Na/22.99 g Na
= **0.869_7 mol Na** (**1 pt**)

0.869_7 mol Na × **2** mol Al/**6** mol Na
= **0.0289_9 mol Al** (**1 pt**)

0.0289_9 mol Al × 26.98 g/1 mol = **7.82_1 g Al** (**1 pt**)

Limiting Reagent:

Na (**1 pt**)

Percent yield:

55.9%

% yield = (actual yield/theoretical yield) × 100%
= 4.37 g/ 7.82_1 g × 100% = **55.9%** (**1 pt**)

3. The production of tin is important because of its many practical uses, such as the delivery of fluoride in toothpaste as SnF_2. Using the following two reactions, determine the equilibrium constant for the third.

(1) $SnO_2(s) + 2CO(g) \rightleftharpoons Sn(s) + 2CO_2(g)$ $K_1 = 14$

(2) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $K_2 = 1.3$

(3) $SnO_2(s) + 2H_2(g) \rightleftharpoons Sn(s) + 2H_2O(g)$ $K_3 = ?$

K_3 = 8.3

Solution: Multiply (2) by 2 and invert:

(1) $SnO_2(s) + 2CO(g) \rightleftharpoons Sn(s) + 2\cancel{CO_2(g)}$ $K_1 = 14$ (remains unchanged)

(2) $2\cancel{CO_2(g)} + 2H_2(g) \rightleftharpoons 2CO(g) + 2H_2O(g)$ $K_2 = (1.3)^{-2}$ (**2 pt – invert & square**)

(3) $SnO_2(s) + 2H_2(g) \rightleftharpoons Sn(s) + 2H_2O(g)$ **$K_3 = K_1 \times (K_2)^{-2} = 14 \times (1.3)^{-2} = 8.2_8$**

(**1 pt**) (**1 pt**)

4. Complete the following. The central atom is underlined. For dipole moment, circle yes or no.

Molecule		**Shape**	**Dipole Moment?**	
$\underline{I}F_2^-$	V = (7 × 3) + 1 = 22 electrons F – I – F AB_2E_3	**LINEAR** (**1 pt**)	Yes	(No) (**1 pt**)
$\underline{Xe}OF_2$	V = 8 + 6 + (2 × 7) = 28 electrons F – Xe – F O	**T – SHAPED** (**1 pt**)	(Yes) (**1 pt**)	No

Bonus Point: The F-Xe-F bond angle in $XeOF_2$ is **<u>180°</u>**. (**1 pt**)