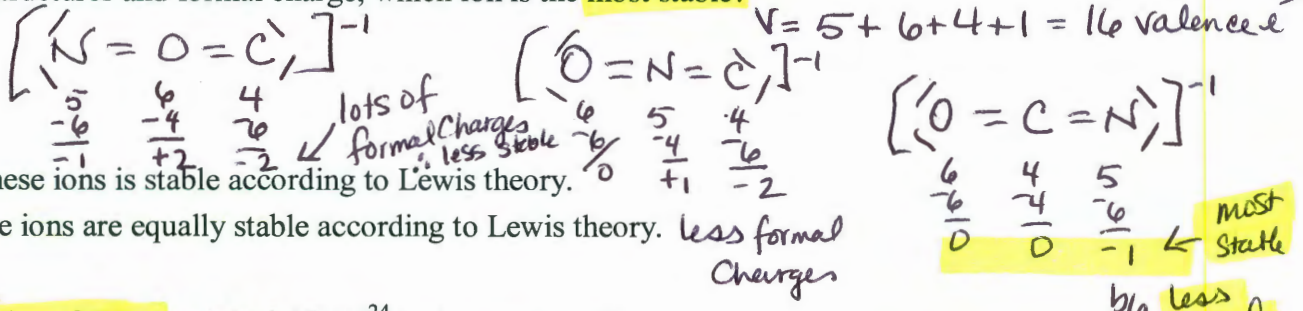
CHEM*1040: FALL 2016 Midterm Solutions

1. Using Lewis structures and formal charge, which ion is the most stable?

   A) NOC^-
   B) ONC^-
   C) OCN^-
   D) None of these ions is stable according to Lewis theory.
   E) All of these ions are equally stable according to Lewis theory.



Part marks

2. How many moles of C_3H_8 contain 4.95×10^{24} hydrogen atoms?

   A) 1.03 moles C_3H_8
   B) 2.74 moles C_3H_8
   C) 8.22 moles C_3H_8
   D) 24.7 moles C_3H_8
   E) 65.8 moles C_3H_8

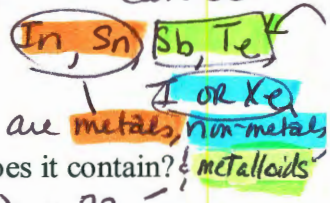
$4.95\times10^{24}\ H\text{ atoms} \times \frac{1\text{ mol H}}{6.022\times10^{23}\ H\text{ atoms}} = 8.22\text{ moles H}$ ← ½ mark

$8.22\text{ mol H} \times \frac{1\text{ mole } C_3H_8}{8\text{ moles H}} = 1.03\text{ moles } C_3H_8$ full mark

3. The *n* and *l* quantum numbers of the "last" electron of an element are n=5 and l=1. → 5p ∴ can be

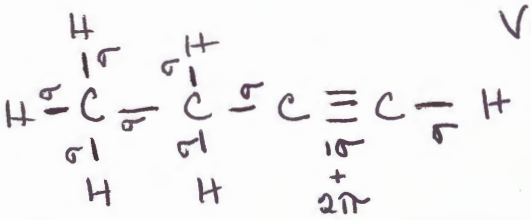
   This element could be a: 1. metal 2. nonmetal 3. metalloid

   A) 1 only B) 2 only C) 3 only D) 1 and 2 only E) 1, 2 and 3



4. Draw the Lewis structure for the molecule CH_3CH_2CCH. How many sigma and pi bonds does it contain?

   A) 11 sigma, 0 pi
   B) 9 sigma, 1 pi
   C) 8 sigma, 3 pi
   D) 9 sigma, 2 pi
   E) 8 sigma, 2 pi



9 σ bonds → form skeleton of molecule
+ 2π in triple bond.

5. If the percent yield for the following reaction is 65.0%, how many moles of $KClO_3$ are needed to produce 1.00 moles of O_2?

$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ 65% efficient.
?mol 1.00mol.

   A) 0.433 moles ✗
   B) 1.50 moles
   C) 0.667 moles
   D) 2.31 moles
   E) 1.03 moles

If rxn 100% ∴ $1.00\text{mol } O_2 \times \frac{2\text{mol } KClO_3}{3\text{mol } O_2} = 0.667$ moles $KClO_3$ needed.

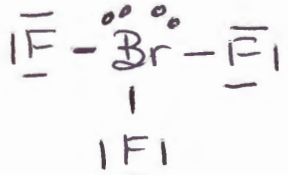
But rxn only 65% efficient ∴ need more $KClO_3$

$x \times \frac{65.0}{100} = 0.667\text{ moles}$; $x = \frac{0.667\text{mol}}{0.650} = 1.03$ moles of $KClO_3$ required

6. Determine the electron geometry or framework for the molecule BrF_3.

   A) Linear
   B) Trigonal planar
   C) Tetrahedral
   D) Trigonal bipyramidal
   E) Octahedral

V = 7 + 3(7) = 28 valence e's



Framework: AB_3E_2 = trig. bipyramidal

Shape: T-shaped.

$V = 0.109\ L$

7. 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?

A) F_2 $MM = 19 \times 2 = 38\ g/mol$

B) Cl_2 $MM = 35.45 \times 2 = 70.9\ g/mol$

C) Br_2 $79.90 \times 2 = 159.8\ g/mol$

D) I_2 $126.9 \times 2 = 253.8\ g/mol$

E) At_2 $210 \times 2 = 420\ g/mol$.

$T = 125°C + 273.15K = 398.15K$

$$n = \frac{PV}{RT} = \frac{1.41\ atm \times 0.109\ L}{0.0821\ \frac{atm\ L}{mol\ K} \times 398.15\ K}$$

$n = 4.70 \times 10^{-3}\ mol$

$$MM = \frac{mass}{moles} = \frac{0.334\ g}{4.70 \times 10^{-3}\ mol} = 71.0\ g/mol$$

8. A 1.00-g sample of the hydrated mineral tröegerite, $(UO_2)_3(AsO_4)_2 \cdot 12H_2O$, has 1.38×10^{21} U atoms. How many arsenic atoms are present in 1.00 g of tröegerite?

A) 9.20×10^{20}

B) 2.07×10^{21}

C) 1.20×10^{22}

D) 1.66×10^{22}

E) 2.40×10^{22}

$$1.38 \times 10^{21}\ U\ atoms \times \frac{1\ formula\ unit}{3\ U\ atoms} \times \frac{2\ As\ atoms}{1\ formula\ unit}$$

$= 9.20 \times 10^{20}$ As atoms.

9. Identify the set of four quantum numbers that could represent the electron lost from a K atom when a K ion is formed.

A) $n = 3, l = 1, m_l = 1, m_S = -\frac{1}{2}$

B) $n = 4, l = 1, m_l = 1, m_S = +\frac{1}{2}$

C) $n = 4, l = 4, m_l = 0, m_S = -\frac{1}{2}$

D) $n = 4, l = 0, m_l = 0, m_S = +\frac{1}{2}$

E) $n = 3, l = 0, m_l = 1, m_S = +\frac{1}{2}$

$^{19}K \equiv [Ar]\,4s^1 \rightarrow {}^{18}K^+ \equiv [Ar]$

electron removed from 4s orbital

$\therefore n = 4$

$l = 0$ $\quad m_S = +\frac{1}{2}$ OR $-\frac{1}{2}$

$m_l = 0$

10. How many photons are contained in a burst of yellow light (589 nm/5.09×10^{14} Hz) from a sodium lamp that contains 609 kJ of energy?

A) 3.37×10^{19} photons

B) 3.06×10^{30} photons

C) 1.80×10^{24} photons

D) 4.03×10^{28} photons

E) 2.48×10^{25} photons

Energy of 1 photon: λ ν $1\ Hz = s^{-1}$

$E = h\nu = 6.626 \times 10^{-34}\ J \cdot s \times 5.09 \times 10^{14}\ s^{-1}$

$= 3.37 \times 10^{-19}$ Joules per photon

$609\ kJ \Rightarrow 609\,000$ Joules $\times \frac{1\ photon}{3.37 \times 10^{-19}\ Joules}$

$\therefore 1.81 \times 10^{24}$ photons

Part Marks

11. How many ions are present in 30.0 mL of a 0.600 M Na_2CO_3 solution?

1 A) 3.25×10^{22} ions 1 mark

B) 2.17×10^{22} ions

½ C) 1.08×10^{22} ions (½)

D) 5.42×10^{22} ions

E) 3.61×10^{22} ions

$V = 30.0\ mL \times \frac{1\ L}{1000\ mL} = 0.0300\ L$

$Na_2CO_{3(aq)} \rightarrow 2Na^+_{(aq)} + CO_{3(aq)}^{2-}$

$\therefore$ 3 ions per Na_2CO_3

$n_{Na_2CO_3} = 0.0300\ L \times 0.600\ \frac{moles}{L} = 0.0180\ moles\ Na_2CO_3$

$0.0180\ moles\ Na_2CO_3 \times \frac{6.022 \times 10^{23}\ Na_2CO_3}{1\ mole} = 1.08 \times 10^{22}\ Na_2CO_3$

½ mark

$1.08 \times 10^{22}\ Na_2CO_3 \times \frac{3\ ions}{1\ Na_2CO_3} = 3.25 \times 10^{22}\ ions$

full mark

2

12. Which of the following statements is true?

A) The first ionization energy of B is greater than that of F. ✗ IE for B < IE for F (IE ↑)

B) The ionic radius of Cl^- is larger than that of S^{2-}. ✗ Radius of S^{2-} > Radius of Cl^- (more e⁻'s)

C) The electronegativity of Cl is greater than that of S. ✓ E.N. for Cl > E.N. for S (EN ↑)

D) The atomic radius of O is larger than that of P. ✗ Radius of O < radius of P (DEC ↓)

E) All are false. ✗

13. Determine the theoretical yield of H_2S (in moles) if 4.0 mol Al_2S_3 and 4.0 mol H_2O are reacted according to the following balanced reaction: $Al_2S_3(s) + 6H_2O(l) \rightarrow 2Al(OH)_3(s) + 3H_2S(g)$

4.0 mol 4.0 mol ?

A) 18 mol H_2S

B) 12 mol H_2S

C) 6.0 mol H_2S

D) 4.0 mol H_2S

E) 2.0 mol H_2S

$4.0\,mol\,Al_2S_3 \times \frac{3\,mol\,H_2S}{1\,mol\,Al_2S_3} = 12\,moles\,H_2S$ to be produced (Excess)

$4.0\,mol\,H_2O \times \frac{3\,mol\,H_2S}{6\,mol\,H_2O} = 2.0\,mol\,H_2S$ to be produced (limiting)

∴ H_2O is limiting reagent + 2.0 mol H_2S is theoretical yield

14. The net ionic equation for the reaction of nitrous acid with lithium hydroxide is

A) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$.

B) $HNO_3(aq) + OH^-(aq) \rightarrow NO_3^-(aq) + H_2O(l)$.

C) $H^+(aq) + NO_2^-(aq) + Li^+(aq) + OH^-(aq) \rightarrow Li^+(aq) + NO_2^-(aq) + H_2O(l)$.

D) $HNO_3(aq) + LiOH(aq) \rightarrow LiNO_3(aq) + H_2O(l)$.

E) $HNO_2(aq) + OH^-(aq) \rightarrow NO_2^-(aq) + H_2O(l)$.

HNO_2 ← NOT a strong acid ∴ does NOT dissociate

LiOH ← a strong base

∴ WA + SB: $HNO_2(aq) + LiOH(aq) \rightarrow LiNO_2(aq) + H_2O(l)$

$HNO_2(aq) + Li^+(aq) + OH^-(aq) \rightarrow Li^+(aq) + NO_2^-(aq) + H_2O(l)$ (spectator ion)

15. A solution is prepared by adding 2.40×10^{-2} moles of solid NaCl to 50.0 mL of 0.100 M $CaCl_2$. What is the molarity of chloride ion in the final solution? Assume the volume of the final solution is 50.0 mL.

A) 0.224 M

B) 0.580 M

C) 0.480 M

D) 0.680 M

E) 0.124 M

$n_{NaCl} = 2.40\times10^{-2}$ moles → $n_{Cl^-} = 2.40\times10^{-2}$ moles

$50.0\,mL \times \frac{1\,L}{1000\,mL} \times \frac{0.100\,moles\,CaCl_2}{L} \times \frac{2\,moles\,Cl^-}{1\,mol\,CaCl_2} = 0.0100\,moles\,Cl^-$

$n_{Cl^-} = 2.40\times10^{-2}$ (NaCl) $+ 0.0100$ ($CaCl_2$) $= 0.0340\,moles\,Cl^-$

$[Cl^-] = 0.0340\,moles\,Cl \times \frac{1000\,mL}{50.0\,mL}$

16. Which of the following atoms has the largest number of unpaired electrons in its ground state?

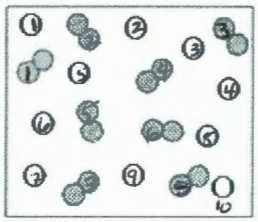
A) Ca (Z = 20) [Ar] $4s^2$ ⇅ no unpaired e⁻'s

B) V (Z = 23) [Ar] $3d^3\,4s^2$ ↑ ↑ ↑ _ _ 3 unpaired e⁻'s

C) Ni (Z = 28) [Ar] $3d^8\,4s^2$ ⇅ ⇅ ⇅ ↑ ↑ 2 unpaired e⁻'s

D) Se (Z = 34) [Ar] $3d^{10}\,4s^2\,4p^4$ ⇅ ⇅ ⇅ ↑ ↑ 2 unpaired e⁻'s

17. Consider the reaction: $2Sb(s) + 3Cl_2(g) \rightarrow 2SbCl_3(s)$. This diagram shows a mixture of Sb and Cl_2, where "O" represents antimony, and each symbol represents 1 mole of the species. How many moles of excess reactant are left over after the reaction is complete?



Sb = 10

Cl_2 = 8

A) 5.3 moles
B) 4.7 moles
C) 2.7 moles
D) 2.3 moles
E) 2.0 moles

$10 \text{ mol Sb} \times \frac{1 \text{ rxn}}{2 \text{ mol Sb}} = 5 \text{ rxns possible (Excess)}$

$8 \text{ mol } Cl_2 \times \frac{1 \text{ rxn}}{3 \text{ mol } Cl_2} = 2.67 \text{ rxns possible (LR)}$

$2.67 \text{ rxns} \times \frac{2 \text{ mol Sb}}{1 \text{ rxn}} \Rightarrow 5.33 \text{ mol Sb will react}$

10 mol Sb (Initial)
− 5.33 mol Sb (reacted)
4.67 mol Sb in excess

18. For, PF_3, OF_2 and PF_4^+, place them in order of **increasing** F-A-F bond angle, where A represents the central atom in each molecule.

A) $PF_3 < OF_2 < PF_4^+$
B) ~~$OF_2 < PF_4^+ < PF_3$~~
C) ~~$PF_4^+ < OF_2 < PF_3$~~
D) $OF_2 < PF_3 < PF_4^+$
E) ~~$PF_4^+ < PF_3 < OF_2$~~

PF_3: $V = 5 + 3(7) = 26 e^-$ — AB_3E — trig. pyramidal — F-A-F < 109.5°

OF_2: $V = 6 + 2(7) = 20 e^-$ — AB_2E_2 — Bent — << 109.5° — SMALLEST

PF_4^+: $V = 5 + 4(7) - 1 = 32 e^-$ — AB_4 — tetrahedral — 109.5°

19. For the reaction between aqueous potassium bromide and silver nitrate, identify the spectator ions.

A) Ag^+ and Br^-
B) K^+ and Br^-
C) Ag^+ and NO_3^-
D) K^+ and NO_3^-
E) There are no spectator ions in this reaction.

KBr $AgNO_3$

$KBr(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgBr(s)$

~~$K^+(aq)$~~ + $Br^-(aq)$ + $Ag^+(aq)$ + ~~$NO_3^-(aq)$~~ → ~~$K^+(aq)$~~ + ~~$NO_3^-(aq)$~~ + $AgBr(s)$

NIE: $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

largest angle.

20. All the following ions have the electronic configuration of a noble gas EXCEPT

A) $Ca^{2+} = 18e^-$ [Ar] B) $Al^{3+} = 10e^-$ [Ne] C) $Ga^{3+} = 28e^-$ D) $H^- = 2e^-$ [He] E) $Cl^- = 18e^-$ [Ar]

21. Potassium perchlorate can be produced from the following reactions:

$Cl_2(g) + 2KOH(aq) \rightarrow KCl(aq) + KClO(aq) + H_2O(l)$

$3KClO(aq) \rightarrow 2KCl(aq) + KClO_3(aq)$

$4KClO_3(aq) \rightarrow 3KClO_4(aq) + KCl(aq)$

How many moles of potassium hydroxide are required to produce 5.00 moles of potassium perchlorate?

($KClO_4$; KOH)

A) 0.625 moles
B) 8.00 moles
C) 20.0 moles
D) 40.0 moles
E) 120. moles

$5.00 \text{ mol } KClO_4 \times \frac{4 \text{ mol } KClO_3}{3 \text{ mol } KClO_4} \times \frac{3 \text{ mol } KClO}{1 \text{ mol } KClO_3} \times \frac{2 \text{ mol KOH}}{1 \text{ mol } KClO}$

= 40.0 moles KOH required

22. $FeSO_4 \cdot 7H_2O$ is used to treat iron deficiency. What is the cation's ground-state electron configuration?

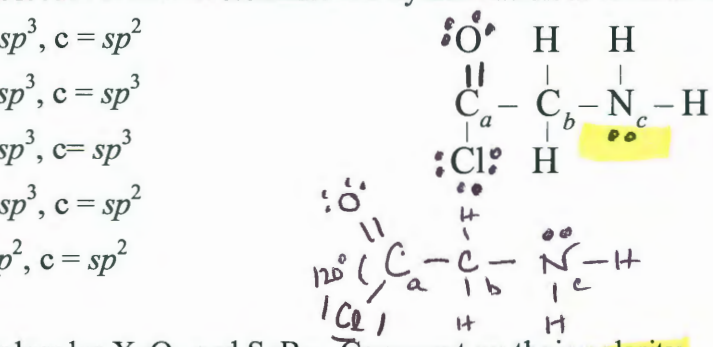
A) [Ar] $3d^8 4s^2$
B) [Ar] $3d^6 4s^2$
C) [Ar] $3d^4 4s^2$
D) [Ar] $3d^5 4s^1$
E) [Ar] $3d^6$

$FeSO_4 \rightarrow Fe^{2+} + SO_4^{2-}$

^{26}Fe : [Ar] $3d^6 4s^2 \xrightarrow{-2e^-} Fe^{2+}$: [Ar] $3d^6$

23. Consider the molecule below. Determine the hybridization at each of the three labelled atoms.

A) a = sp^2, b = sp^3, c = sp^2
B) a = sp^2, b = sp^3, c = sp^3
C) a = sp^3, b = sp^3, c = sp^3
D) a = sp^3, b = sp^3, c = sp^2
E) a = sp, b = sp^2, c = sp^2



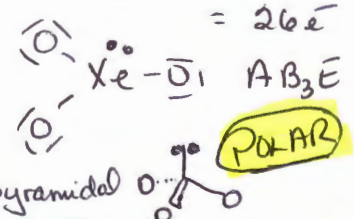
$V = 6 + 2(4) + 7 + 5 + 2 + 2 = 30e^-$ in total.

a: $AB_3 \Rightarrow sp^2$ 120°
b) $AB_4 \Rightarrow sp^3$ 109.5°
C: $AB_3E \Rightarrow sp^3$ <109.5°

24. Consider the molecules XeO_3 and $SeBr_2$. Comment on their polarity.

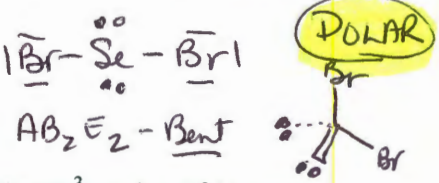
A) Both XeO_3 and $SeBr_2$ are polar.
B) XeO_3 is polar while $SeBr_2$ is nonpolar.
C) XeO_3 is nonpolar while $SeBr_2$ polar.
D) Both XeO_3 and $SeBr_2$ are nonpolar.

XeO_3: $V = 8 + 3(6) = 26e^-$



AB_3E trig. pyramidal POLAR

$SeBr_2$ $V = 6 + 2(7) = 20e^-$



AB_2E_2 - Bent POLAR

25. How many millilitres of ozone gas at 298 K and 760 mmHg need to react with 4.50×10^{-3} moles of aqueous KI according to the equation: $O_3(g) + 2I^-(aq) + H_2O(l) \rightarrow O_2(g) + I_2(s) + 2OH^-(aq)$

? mL = 4.50×10⁻³ mol

NET IONIC EQN

T = 298 K

760 mmHg = 760 Torr = 1 atm

A) 11.1 mL
B) 55.0 mL
C) 1.10×10^2 mL
D) 165 mL
E) 2.20×10^2 mL

$4.50 \times 10^{-3}\ mol\ I^-_{(aq)} \times \frac{1\ mol\ O_3}{2\ mol\ I^-} = 2.25 \times 10^{-3}\ mol\ O_3$

$V = \frac{nRT}{P} = \frac{2.25 \times 10^{-3}\ mol\ O_3 \times 0.0821\ \frac{atm \cdot L}{mol \cdot K} \times 298\ K}{1\ atm}$

$V = 0.0550\ L \times \frac{1000\ mL}{1\ L} = 55.0\ mL$

KI(aq) → K^+_{aq} + $I^-_{(aq)}$ Spectator ion.

Bonus Question

26. Which reagent could not be used to separate Br^- from CO_3^{2-} when added to an aqueous solution containing both?

A) $AgNO_3(aq)$
B) $CaCl_2(aq)$
C) $Cu(ClO_4)_2(aq)$
D) $Ba(OH)_2(aq)$
E) $FeSO_4(aq)$

$AgNO_{3(aq)} + Br^-_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow AgBr_{(s)} + Ag_2CO_{3(s)}$ ← Can't Separate

$CaCl_{2(aq)} + Br^-_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)} + Ca^{2+}_{(aq)} + Br^-_{(aq)}$ CAN Sep.

$Cu(ClO_4)_2 + Br^-_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CuCO_{3(s)} + Br^-_{(aq)}$ " — "

$Ba(OH)_{2(aq)} + Br^-_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow BaCO_{3(s)} + Br^-_{(aq)}$ " — "

$FeSO_{4(aq)} + Br^-_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow FeCO_{3(s)} + Br^-_{(aq)}$ " — "