F'17 CHEM*1040 Midterm - Version 05 - Solutions

1. What volume of 0.538 *M* H_2SO_4 is required to neutralize 36.1 mL of 0.632 *M* NaOH?

A) 84.8 mL
B) 30.7 mL
C) 42.4 mL
D) 21.2 mL
E) 15.4 mL

D

Rxn: $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

0.538 moles/L 36.1 mL 0.632 mol/L

$0.632 \text{ mol NaOH} \times \frac{36.1 \text{ mL}}{1} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mole } H_2SO_4}{2 \text{ mol NaOH}} \times \frac{1 \text{ L}}{0.538 \text{ moles } H_2SO_4}$

$V = 0.02120 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 21.2 \text{ mL}$

¼ mark for C - need to write a balanced equation to determine correct mole ratio for calculation!

2. Give the theoretical yield of CO_2, in moles, for the reaction $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ where 4.00 moles of C_8H_{18} react with 4.00 moles of O_2.

A) 0.500 moles
B) 64.0 moles
C) 16.0 moles
D) 32.0 moles
E) 2.56 moles

E

$4.00 \text{ mol } C_8H_{18} \times \frac{16 \text{ mol } CO_2}{2 \text{ mol } C_8H_{18}} = 32 \text{ mol } CO_2$ would be produced

$4.00 \text{ mol } O_2 \times \frac{16 \text{ mol } CO_2}{25 \text{ mol } O_2} = 2.56 \text{ mol } CO_2$ would be produced

$\therefore O_2$ is the limiting reagent & C_8H_8 is in Excess

$\therefore$ the theoretical yield of CO_2 would be 2.56 moles.

3. How many moles of sulfate ions are there in a 0.545-L solution of 0.489 *M* $Al_2(SO_4)_3$?

A) 0.267 mol
B) 0.800 mol
C) 3.34 mol
D) 0.0888 mol
E) 2.69 mol

B

$Al_2(SO_4)_{3(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3SO_4^{2-}{}_{(aq)}$

0.545 L × 0.489 mol/L

$0.2665 \text{ mol } Al_2(SO_4)_3 \times \frac{3 \text{ mole } SO_4^{2-}}{1 \text{ mol } Al_2(SO_4)_3} = 0.7995 \text{ moles } SO_4^{2-}$

$= 0.800 \text{ mol } SO_4^{2-}$

4. Rank the following ions in order of **decreasing** ionic radius: Na^+, F^-, O^{2-}, Mg^{2+} and S^{2-}.

A) $Mg^{2+} > S^{2-} > Na^+ > F^- > O^{2-}$
B) $O^{2-} > F^- > Na^+ > Mg^{2+} > S^{2-}$
C) $S^{2-} > O^{2-} > F^- > Na^+ > Mg^{2+}$
D) $Mg^{2+} > Na^+ > F^- > O^{2-} > S^{2-}$
E) $O^{2-} > S^{2-} > F^- > Na^+ > Mg^{2+}$

C

anions > atoms > cations

$S^{2-} > O^{2-}$

S is below O in periodic table $\therefore S > O$

$Na^+ > Mg^{2+}$

5. What products result from mixing aqueous solutions of $Pb(ClO_3)_2(aq)$ and $K_3PO_4(aq)$?

A) $Pb_3(PO_4)_2(s)$, $K^+(aq)$, and $ClO_3^-(aq)$
B) $PbPO_4(s)$ and $K_3(ClO_3)_2(aq)$
C) $Pb_3(PO_4)_2(s)$ and $KClO_3(s)$
D) $PbPO_4(aq)$ and $KClO_3(aq)$
E) $Pb_3(PO_4)_2(aq)$ and $KClO_3(s)$

A

$3Pb(ClO_3)_{2(aq)} + 2K_3PO_{4(aq)} \rightarrow 6KClO_{3(aq)} + Pb_3(PO_4)_{2(s)}$

soluble (Rule #2) | soluble (Rule #1) | soluble (Rule #1) | insoluble (Rule #5)

Products: $K^+_{(aq)}$, $ClO_3^-{}_{(aq)}$ + $Pb_3(PO_4)_{2(s)}$

6. Which of the following ground-state electron configurations corresponds to an atom having the largest ionization energy

A) $[Ar]3d^{10}4s^24p^3$ As
B) $[Ne]3s^23p^3$ P
C) $[Kr]4d^{10}5s^25p^3$ Sb
D) $[Ne]3s^23p^2$ Si
E) $[Xe]4f^{14}5d^{10}6s^26p^3$ Bi

B

I.E. INC →
↑

Si P Highest I.E.
As
Sb
Bi lowest I.E.

Weak electrolytes, such as weak acids , i.e., not one of the 6 strong acids, do NOT dissociate!

7. What is the net ionic equation for the acid–base reaction that occurs when an excess of a sodium hydroxide solution is added to a solution of H_2SO_3?

A) $H_2SO_3(aq) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + 2H_2O(l)$
B) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
C) $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
D) $2H^+(aq) + SO_3^{2-}(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow 2Na^+(aq) + SO_3^{2-}(aq) + 2H_2O(l)$
E) $H_2SO_3(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + SO_3^{2-}(aq)$ NIE

E

SB = soluble
WA doesn't dissociate!
$2NaOH_{(aq)} + H_2SO_{3(aq)} \rightarrow 2H_2O_{(l)} + Na_2SO_{3(aq)}$ soluble
spectator ion
$2Na^+_{(aq)} + 2OH^-_{(aq)} + H_2SO_{3(aq)} \rightarrow 2H_2O_{(l)} + 2Na^+_{(aq)} + SO_3^{2-}$

8. A 15-g sample of lithium reacted with 15 g of fluorine to form lithium fluoride, according to the balance equation: $2Li + F_2 \rightarrow 2LiF$. Once the reaction is complete, what will be present?

A) 0.789 mol of lithium fluoride only
B) 0.789 mol of lithium fluoride and 1.37 mol of lithium
C) 2.16 mol of lithium fluoride and 0.395 mol of fluorine
D) 2.16 mol of lithium fluoride only
E) none of these

B

$15\,g\,Li \times \frac{1\,mol}{6.94\,g\,Li} = 2.16$ moles Li
2:2 Ratio b/w Li + LiF
∴ 2.16 moles LiF produced

$15\,g\,F_2 \times \frac{1\,mol}{(2\times19.00)\,g\,F_2} = 0.395\,mol\,F_2$ (EXCESS)

$0.395\,mol\,F_2 \times \frac{2\,mol\,LiF}{1\,mol\,F_2} = 0.789$ mol LiF produced

If 0.789 mol of LiF produced,
0.789 moles of Li used up. ∴ 2.16 moles Li − 0.789 mol Li = 1.37 moles Li left over.
∴ LR

9. $Mn(C_2H_3O_2)_3 \cdot 2H_2O$ is used as an oxidizing agent in organic synthesis and material science. What is the cation's ground-state electron configuration?

A) [Ar] $3d^54s^2$
B) [Ar] $3d^34s^1$
C) [Ar] $3d^84s^2$
D) [Ar] $3d^4$
E) [Ar] $3d^24s^2$

D

$C_2H_3O_2^-$ ≡ acetate ∴ Mn^{3+}

Mn : [Ar] $4s^2 3d^5$ ground state → [Ar] $3d^5 4s^2$

↑ ↑ ↑ ↑ ↑ 4s

Mn^{3+} : [Ar] $3d^4$

remove 3e⁻'s from outer most orbital

Atom needing more electrons to reach "8" must be central atom, i.e., N - N - O

10. Place N_2O, NCl_3 and NO_2^- in order of **increasing** X-A-X bond angle, where A represents the central atom and X represents the outer atoms.

A) $NCl_3 < NO_2^- < N_2O$
B) $N_2O < NO_2^- < NCl_3$
C) $NCl_3 < N_2O < NO_2^-$
D) $NO_2^- < N_2O < NCl_3$
E) $NO_2^- < NCl_3 < N_2O$

A

N_2O: V = 2(5) + 6 = 16 e⁻
N=N=O, AB_2
linear
∴ 180° angles LARGEST

NCl_3 : V = 5 + 3(7) = 26 e⁻
AB_3E
Tetrahedral framework
Trigonal pyramidal shape
∴ < 109.5°

NO_2^- : V = 5 + 2(6) + 1 = 18 e⁻
AB_2E ∴ < 120°
Framework: trigonal planar
Shape: Bent

Smallest

F'17 CHEM*1040 Midterm - Version 05 - Solutions

11. Consider the following reaction: $2A + B \rightarrow 3C + D$
If 3.0 mol A and 2.0 mol B react to form 4.0 mol C, what is the percent yield of this reaction?

A) 50 %
B) 67 %
C) 75 %
D) 89 %
E) 100 %

D

$3.0\,\text{mol A} \times \frac{3\,\text{mol C}}{2\,\text{mol A}} = 4.5\,\text{mol C}$ (LR) ∴ Theoretical yield

$2.0\,\text{mol B} \times \frac{3\,\text{mol C}}{1\,\text{mol B}} = 6\,\text{mol C}$ (Excess)

$\%\text{ yield} = \frac{\text{actual}}{\text{theoretical}} \times 100\% = \frac{4.0\,\text{mol C}}{4.5\,\text{mol C}} \times 100\% = 89\%$

12. The concentration of Pb^{2+} in a sample of wastewater is to be determined by using gravimetric analysis. To a 100.0-mL sample of the wastewater is added an excess of sodium carbonate, forming the insoluble lead (II) carbonate (267.2092 g/mol) according to the balanced equation given below. The solid lead (II) carbonate is dried, and its mass is measured to be 0.4078 g. What was the concentration of Pb^{2+} in the original wastewater sample

$$Pb^{2+}(aq) + Na_2CO_3(aq) \rightarrow PbCO_3(s) + 2Na^+(aq)$$

A) 1.090 *M*
B) 0.001526 *M*
C) 0.01526 *M*
D) 0.004078 *M*
E) 65.52 *M*

C

100.0 mL Excess $0.4078\,\text{g} \times \frac{1\,\text{mol}}{267.2092\,\text{g}} = 1.5261 \times 10^{-3}\,\text{mol } PbCO_3$

1:1 ratio b/w Pb^{2+} & $PbCO_3$

∴ 1.5261×10^{-3} moles of Pb^{2+} present

$[Pb^{2+}] = \frac{1.5261 \times 10^{-3}\,\text{moles}}{100.0\,\text{mL}} \times \frac{1000\,\text{mL}}{1\,\text{L}} = 0.015261\,\frac{\text{mol}}{\text{L}}$

13. Draw the Lewis structure for N_2H_2. What is the hybridization on the N atoms?

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

E

$V = (2\times5) + 2 = 12\,e^-$

H–N = N–H

AB_2E
Steric # = 3
Framework: Trig. Planar
∴ hybridizat = sp^2

14. Which of the following statements is incorrect?

A) The set of quantum numbers $n = 3, l = 2, m_l = 0, m_s = -½$ is not permitted because $m_l = 0$.
B) The set of quantum numbers $n = 2, l = 2, m_l = 1, m_s = -½$ is not permitted because $n = l$. ✓
C) The set of quantum numbers $n = 3, l = 2, m_l = 1, m_s = +½$ is permitted. ✓
D) The set of quantum numbers $n = 3, l = 2, m_l = 3, m_s = -½$ is not permitted because m_l exceeds l. ✓
E) The set of quantum numbers $n = 4, l = 3, m_l = -1, m_s = 0$ is not permitted because $m_s = 0$. ✓

A

Atom needing more electrons to reach "8" must be central atom, i.e., N - N - O

15. Which of the following statements best describes N_2O?

A) The molecular geometry is bent and the molecule is nonpolar.
B) The molecular geometry is linear and the molecule is nonpolar. ✗
C) The molecular geometry is linear and the molecule is polar. ✓
D) The molecular geometry is trigonal planar and the molecule is nonpolar.
E) The molecular geometry is bent and the molecule is polar.

C

$V = (2\times5) + 6 = 16\,e^-$ linear & polar

$N = N \rightarrow O$

O is more electroneg than N
∴ N = O bond is polar

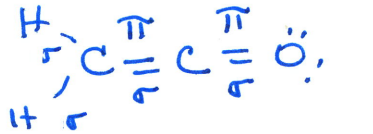
½ mark for B - linear correct; non-polar incorrect!

16. According to valence-bond theory, the bonding in ketene, H_2CCO, is best described as

A) five π bonds.
B) three σ bonds and two π bonds.
C) four σ bonds and two π bonds.
D) four σ bonds and one π bond.
E) five σ bonds.

C

$V = 2+4+4+6 = 16\,e^-$



$\therefore\ 4\sigma + 2\pi$

17. What volume of ammonia (NH_3) gas, measured at 0.8688 atm and 58.2°C, is required to produce 48.9 millimoles of ammonium sulfate according to the following balanced chemical equation?

$$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$$

A) 3.06 L
B) 1.53×10^3 L
C) 155 L
D) 3.06×10^3 L
E) 1.53 L

A

P

$T = 58.2°C + 273.15K = 331.15K$

48.9 mmol

$$48.9\,\text{mmol}\ (NH_4)_2SO_4 \times \frac{1\,\text{mol}}{1000\,\text{mmol}} \times \frac{2\,\text{moles}\ NH_3}{1\,\text{mol}\ (NH_4)_2SO_4} = 0.0978\,\text{mol}\ NH_3$$

$$V = \frac{nRT}{P} = \frac{0.0978\,\text{mol} \times 0.0821\,\frac{\text{atm·L}}{\text{mol·K}} \times 331.15\,\text{K}}{0.8688\,\text{atm}}$$

$V = 3.060\,L \Rightarrow 3.06$ Litres (sig figs)

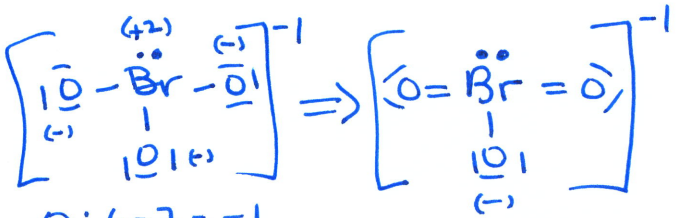
18. The Lewis structure for BrO_3^- that minimizes formal charge has the central atom surrounded by

A) two bonding pairs and two lone pairs of electrons.
B) four bonding pairs and one lone pair of electrons.
C) three bonding pairs and no lone pairs of electrons.
D) five bonding pairs and one lone pair of electrons.
E) three bonding pairs and one lone pair of electrons.

D

½ for E

$V = 7 + 3(6) + 1 = 26\,e^-$



Formal charges: O: 6 − 7 = −1
Br: 7 − 5 = +2

reduce charges down to

19. Sorbose, $C_6H_{12}O_6$, is used in making vitamin C. A sorbose sample containing 72.0 g of carbon atoms also contains _____ g of hydrogen atoms.

A) 24.2
B) 6.06
C) 8.65×10^2
D) 144
E) 12.1

E

$$72.0\,\text{g C} \times \frac{1\,\text{mol C}}{12.01\,\text{g C}} \times \frac{12\,\text{moles H atoms}}{6\,\text{moles C atoms}} \times \frac{1.01\,\text{g H}}{1\,\text{mol H}}$$

$= 12.1$ g of H atoms

20. What is the frequency of photons that have molar energy of 441 kJ/mol?

A) 2.20×10^{-10} Hz
B) 3.68×10^6 Hz
C) 1.10×10^{15} Hz
D) 4.51×10^{-31} Hz
E) 7.33×10^{-19} Hz

C

$$\frac{441\,\text{kJ}}{1\,\text{mol photons}} \times \frac{1000\,\text{J}}{1\,\text{kJ}} \times \frac{1\,\text{mol photons}}{6.022\times10^{23}\,\text{photons}} = 7.32\times10^{-19}\,\text{J/photon}$$

$E = h\nu = 7.32\times10^{-19}\,\text{J} = 6.626\times10^{-34}\,\text{J·s} \times \text{frequency}$

$\nu = 1.1047\times10^{15}\,s^{-1} = 1.10\times10^{15}\,\text{Hz}$

$(4\times2)+2+2 = 12$ atoms

21. In 0.500 mol of dimethylhydrazine, $(CH_3)_2N_2H_2$, there are

A) 3.01×10^{22} molecules.
B) 1.51×10^{23} atoms.
C) 1.81×10^{24} atoms.
E D) 3.01×10^{24} molecules.
(E) 3.61×10^{24} atoms.

$0.500\ \text{mol}\ (CH_3)_2N_2H_2 \times \frac{6.022\times10^{23}\ \text{molecules}}{1\ \text{mole}}$

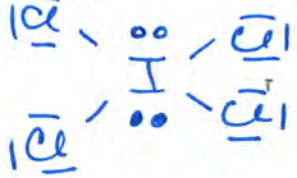
$= 3.011\times10^{23}$ molecules of $(CH_3)_2N_2H_2$

$3.011\times10^{23}\ \text{molecules} \times \frac{12\ \text{atoms}}{1\ \text{molecule}} = 3.61\times10^{24}$ atoms

22. What is the molecular geometry of the ICl_4^- ion?

A) tetrahedral
(B) square planar
C) seesaw
B D) square pyramidal
E) octahedral

$V = 7+4(7)+1 = 36\ e^-$



AB_4E_2

Framework: Octahedral

Molecular Geometry or Shape: Sq. planar

23. A 6.32-L cylinder contains 7.29 g of methane, CH_4, at a pressure of 3020 mmHg. What is the temperature of the gas?

(A) 400°C
B) 946°C
A C) 4910°C
D) -124°C
E) 673°C ½ mark for E

$MM = 12.01 + 4(1.01) = 16.05$ g/mol

$P = 3020\ \text{mmHg} \times \frac{1\ \text{atm}}{760\ \text{mmHg}} = 3.9737$ atm.

$\#\text{ moles } CH_4: 7.29\ \text{g} \times \frac{1\ \text{mol}}{16.05\ \text{g}} = 0.4542$ moles CH_4

$T = \frac{PV}{nR} = \frac{3.9737\ \text{atm} \times 6.32\ \text{L}}{0.4542\ \text{mol} \times 0.0821\ \frac{\text{atm·L}}{\text{mol·K}}}$

$T = 673.5\text{K} \Rightarrow 673.5 - 273.15 = 400°C$

24. Identify the set of four quantum numbers that could represent the electron gained by a Br atom when a Br ion is formed.

A) $n=5, l=1, m_l=-1, m_S=+½$ 5p
(B) $n=4, l=1, m_l=1, m_S=-½$ 4p
B C) $n=4, l=2, m_l=1, m_S=-½$ 4d
D) $n=4, l=0, m_l=1, m_S=+½$ 4s
E) $n=3, l=2, m_l=2, m_S=+½$ 3d

Br : $[Ar]\ 3d^{10}4s^24p^5$

Br^- : $[Ar]\ 3d^{10}4s^24p^6$

$n = 4$

$l = 1$