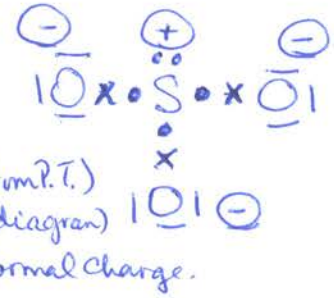
GREY

PART A: Multiple Choice Section [2 points each]

1. Following the octet rule, the formal charges on the sulfur and oxygen atoms in the sulfite ion, SO_3^{2-}, respectively, are

A) +1 and -1
B) +1 and -2
C) +2 and -2
D) +4 and -2
E) +6 and -2

A



$V = 6 + 3(6) + 2 = 26\,e^-$; $-24\,e^-$; $2\,e^-$

S: $6\,e^-$ (from Periodic Table) $-5\,e^-$ (from Lewis diagram) $+1$ Formal Charge

O: $6\,e^-$ (from P.T.) $-7\,e^-$ (diagram) -1 Formal Charge.

2. How many oxygen atoms are present in 2.0 moles of copper (II) perchlorate hexahydrate, $Cu(ClO_4)_2 \cdot 6H_2O$?

A) 1.2×10^{24}
B) 7.2×10^{24}
C) 9.6×10^{24}
D) 1.2×10^{25}
E) 1.7×10^{25}

E

$(4\times2)+6 = 14$

$2\,mol\,Cu(ClO_4)_2\cdot6H_2O \times \frac{6.022\times10^{23}\,molecules}{1\,mole\,Cu(ClO_4)_2\cdot6H_2O} \times \frac{14\,oxygen\,atoms}{1\,molecule}$

$= 1.7\times10^{25}$ oxygen atoms

3. A steel tank contains carbon dioxide at 34°C and is at a pressure of 13.0 atm. Determine the internal gas pressure when the tank and its contents are heated to 100°C.

A) 38.2 atm
B) 15.8 atm
C) 10.7 atm
D) 9.4 atm
E) 1.9 atm

B

$PV = nRT$; V + n are constant

$T_1 = 34°C + 273.15 = 307.15\,K$ $\quad P_1 = 13.0\,atm$

$T_2 = 100°C + 273.15 = 373.15\,K$ $\quad P_2 = ?$

$\therefore \frac{P_1}{T_1} = \frac{nR}{V} = \frac{P_2}{T_2}$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$; $P_2 = \frac{P_1 T_2}{T_1} = \frac{13.0\,atm \times 373.15\,K}{307.15\,K} = 15.8\,atm$

4. Suppose that the electron spin quantum number could have three possible values. Which of the following atomic numbers would not correspond to a noble gas?

A) 3 ✓
B) 15 ✓
C) 27 ✓
D) 42 ✗
E) 81 ✓

D

m_s normally has values of $+\frac{1}{2}$ & $-\frac{1}{2}$ resulting in each orbital holding only $2\,e^-$'s

↳ what if 3? Each orbital would hold 3

He: atomic # = 2; 1 orbital w/ $2\,e^-$'s → 1 orbital w/ 3.

∴ New atomic # = 3

Ne: $10/_{2\,e^-\,per\,orbital} = 5 \times 3\,e^-\,per\,orbital = 15$

Ar: $18/_2 \times 3 = 27$ $\quad$ Xe: $\frac{54}{2} \times 3 = 81$

Kr: $36/_2 \times 3 = 54$

5. In the direct reaction of $Si_{(s)}$ with $Cl_{2(g)}$ the yield of $SiCl_{4(l)}$ is 55.0%. How many moles of chlorine gas must be reacted with excess silicon in order to obtain 2.00 moles of $SiCl_4$?

A) 0.500 moles
B) 2.20 moles
C) 3.64 moles
D) 4.00 moles
E) 7.27 moles

E

$Si_{(s)} + 2Cl_{2(g)} \rightarrow SiCl_{4(l)}$ $\quad$ Rxn 55% efficient

Excess ? mol $\quad$ 2.00 moles $\quad$ ∴ need more Cl_2 than if 100%.

$2.00\,mol\,SiCl_{4(l)} \times \frac{2\,mol\,Cl_{2(g)}}{1\,mole\,SiCl_{4(l)}} = 4.00\,moles\,Cl_2$ if yield 100%

$\frac{4.00\,moles}{x} = \frac{55}{100}$; $x = 7.27\,moles\,Cl_2$ required to produce 2.00 moles $SiCl_4$ @ 55% yield

KEY

6. Predict the shape of SeF_3^+.

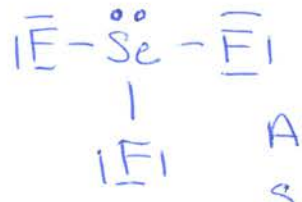
$V = 6 + 3(7) - 1 = 26\ e^-$

$-24\ e^-$

$2\ e^-$

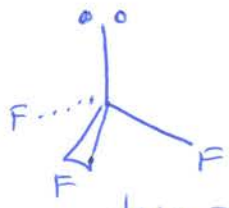
A) trigonal planar
B) trigonal pyramidal
C) trigonal bipyramidal
D) seesaw
E) T-shaped

B



AB_3E

S.N. = 4



trig. pyramidal.

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

I. An excited atom can return to a ~~higher~~ lower energy level by emitting light energy. F
II. An atom can be excited to a higher energy level by absorption of light energy. T
III. The frequency and wavelength of light are inversely proportional. T

A) I. only
B) II. only
C) I. and III. only
D) II. and III. only
E) All three statements are true.

D

$E = h\nu = \frac{hc}{\lambda}$

$\nu \propto 1/\lambda$

8. A 20.0 mL sample of an element with a density of 3.0 g/mL contains 4×10^{23} atoms. What is the atomic weight of this element?

atomic weight $\equiv$ g/mol

$3.0\ g/mL \times 20.0\ mL = 60\ g$

$4\times10^{23}\ atoms \times \frac{1\ mole}{6.022\times10^{23}\ atoms} = 0.6642\ moles$

$\therefore \frac{60\ g}{0.6642\ mol} = 90\ g/mol$

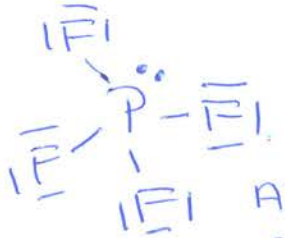
A) 300
B) 90
C) 60
D) 40
E) 10

B

9. According to the VSEPR theory, the F –P –F bond angles in the PF_4^- ion are predicted to be

A) < 90° and < 120°
B) < 109.5°
C) 109.5° only
D) 90° and 120°
E) 180° only

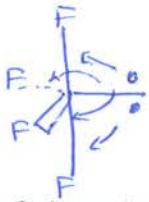
A



$V = 5 + 4(7) + 1 = 34\ e^-$

$-32\ e^-$

$2\ e^-$



AB_4E

S.N = 5

Angles will be less than 90°, 120°, 180°

10. What volume of 0.332 M $Fe(NO_3)_3$ solution contains 0.3736 moles of nitrate ions?

A) 1.13×10^3 mL
B) 413 mL
C) 375 mL
D) 125 mL
E) 6.78 mL

C

$0.3736\ mol\ NO_3^- \times \frac{1\ mol\ Fe(NO_3)_2}{3\ mol\ NO_3^-}$

$= 0.1245\ mol\ Fe(NO_3)_2 \times \frac{1\ L}{0.332\ mol\ Fe(NO_3)_2} \times \frac{1000\ mL}{1\ L}$

$= 375\ mL$

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11. Which of the following statements is true?

A) The first ionization energy of H is greater than that of He. F I.E. ↑ L→R ∴ He > H

(B) The ionic radius of Fe^{+} is larger than that of Fe^{3+}. T As e⁻ removed, radius shrinks ∴ $Fe^{+} > Fe^{3+}$

B

C) The electronegativity of P is greater than that of Cl F E.N ↑ from L→R ∴ Cl > P

D) The atomic radius of Li is larger than that of Cs. F

E) All are false.

atomic rad. ↑ from top to bottom b/c energy level increases

12. The spectator ions in the reaction between $HF_{(aq)}$ and $KOH_{(aq)}$ are

Weak Acid Strong base - fully dissociates

Based on Table 4.3, HF is a weak acid ∴ does not dissociate fully.

A) H^{+}, OH^{-}, F^{-} and K^{+}

B) OH^{-}, F^{-} and K^{+}

C) F^{-} and K^{+}

E D) OH^{-} and F^{-}

(E) K^{+} only

$HF_{(aq)} + KOH_{(aq)} \rightarrow KF_{(aq)} + H_2O_{(l)}$

$\therefore HF_{(aq)} + \cancel{K^{+}_{(aq)}} + OH^{-}_{(aq)} \rightarrow \cancel{K^{+}_{(aq)}} + F^{-}_{(aq)} + H_2O_{(l)}$ (K⁺ = spectator)

NIE: $HF_{(aq)} + OH^{-}_{(aq)} \rightarrow F^{-}_{(aq)} + H_2O_{(l)}$

13. If 6.672×10^{-3} moles of KOH is required to completely neutralize 25.00 mL of an aqueous solution of phosphoric acid, H_3PO_4, what is the concentration of the phosphoric acid solution?

A) 0.2669 M

B) 0.8007 M

(C) 0.08896 M

C D) 0.1345 M

E) 0.1778 M

$3KOH_{(aq)} + H_3PO_{4(aq)} \rightarrow K_3PO_{4(aq)} + 3H_2O_{(l)}$

6.672×10^{-3} mol 25.00mL × 1L/1000mL = 0.02500L ?[ ]

$6.672\times10^{-3}\ \cancel{\text{mol KOH}} \times \frac{1\ \text{mol}\ H_3PO_4}{3\ \cancel{\text{mol KOH}}} = 2.224\times10^{-3}\ \text{mol}\ H_3PO_4$

$\frac{2.224\times10^{-3}\ \text{mol}\ H_3PO_4}{0.02500\text{L}} = 0.08896\text{M}$

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

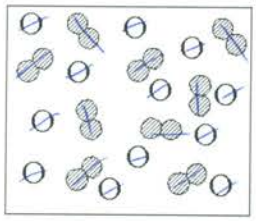
A) Sn (Z = 50) $[Kr]\,4d^{10}5s^{2}5p^{2}$ ↑↓ ↑ ↑ — (5p) 2 unpaired e⁻'s

B) Rh (Z = 45) $[Kr]\,4d^{7}5s^{2}$ ↑↑ ↑ ↑ ↑ ↑ (4d) ↑↓ (5s) 3 unpaired e⁻'s

C C) Mo (Z = 42) $[Kr]\,4d^{5}5s^{1}$ ↑ ↑ ↑ ↑ ↑ ↑ (4d/5s) 6 unpaired e⁻'s

D) Sr (Z = 38) $[Kr]\,5s^{2}$ ↑↓ (5s) no unpaired e⁻'s

15. Consider the reaction: $2P_{(s)} + 5Cl_{2(g)} \rightarrow 2PCl_{5(s)}$. This diagram shows a mixture of P and Cl_2, where "O" represents phosphorus, and each symbol represents 1 mole of the species. How many moles of excess reactant are left over after the reaction is complete?



P = 12 mol.

Cl_2 = 9 mol.

A) 8.4 moles

B) 8.0 moles

C) 4.2 moles

A D) 3.6 moles

E) 3.0 moles

$12\ \cancel{\text{mol P}} \times \frac{1\ \text{Rxn}}{2\ \cancel{\text{mol P}}} = 6\ \text{Rxns possible}$ ∴ in excess

$9\ \cancel{\text{mol Cl}_2} \times \frac{1\ \text{Rxn}}{5\ \cancel{\text{mol Cl}_2}} = 1.8\ \text{Rxn possible}$ ∴ Limiting Reagent

If only 1.8 Rxns possible: $1.8\ \cancel{\text{Rxns}} \times \frac{2\ \text{mol P}}{1\ \cancel{\text{Rxn}}} = 3.6\ \text{mol P}$ used up

12 moles P − 3.6 moles P used = 8.4 moles remain

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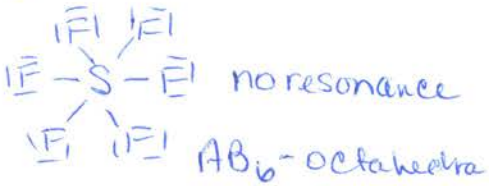
16. For SF_6 and N_3^-, resonance forms can be written for

A) Neither
B) SF_6 only
C) N_3^- only
D) Both

C

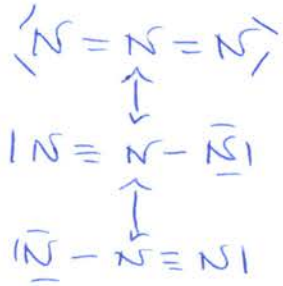
SF_6 : $V = 6 + 6(7) = 48e^-$



no resonance

AB_6 - octahedral

N_3^- : $V = (5 \times 3) + 1 = 16e^-$



resonance

17. Acid rain can be produced through the sequence of reactions that follow:

$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$ ← intermediate

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

How many moles of H_2SO_4 will be produced from 5.00 moles of FeS_2?

A) 1.25 moles
B) 2.50 moles
C) 5.00 moles
D) 10.0 moles
E) 20.0 moles

D

$5.00\,mol\,FeS_2 \times \frac{8\,mol\,SO_2}{4\,mol\,FeS_2} \times \frac{2\,mol\,SO_3}{2\,mol\,SO_2} \times \frac{1\,mol\,H_2SO_4}{1\,mol\,SO_3}$

$= 10.0$ moles H_2SO_4 will be produced.

18. What is the ground-state electron configuration for the cation in $TiCl_2 \cdot 6H_2O$?

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

D

Ti^{2+} ($18e^-$)

Ti ($Z = 22$) : $[Ar]\,4s^2 3d^2$ → Grnd. State : $[Ar]\,3d^2 4s^2$ (Periodic Table)

Ti^{2+} - remove 2 valence e^- : $[Ar]\,3d^2 4s^2$

- must be outermost e^-'s ↳ $[Ar]\,3d^2$

19. If 0.0100 moles hydrochloric acid, HCl, is completely neutralised with 0.250 M $Sr(OH)_2$, how many mL of strontium hydroxide is required?

A) 20.0 mL
B) 25.0 mL
C) 40.0 mL
D) 50.0 mL
E) 80.0 mL

A

$2HCl(aq) + Sr(OH)_2(aq) \rightarrow SrCl_2(aq) + 2H_2O(l)$

0.0100 mol 0.250 mol/L ? mL

$0.0100\,mol\,HCl \times \frac{1\,mol\,Sr(OH)_2}{2\,mol\,HCl} \times \frac{1\,L}{0.250\,mol\,Sr(OH)_2} \times \frac{1000\,mL}{1\,L} = 20.0\,mL$

20. Consider the molecules I_3^- and XeF_4. Comment on their polarity.

A) Both I_3^- and XeF_4 are polar.
B) I_3^- is polar while XeF_4 is nonpolar.
C) XeF_4 is polar while I_3^- is nonpolar.
D) Both I_3^- and XeF_4 are nonpolar.

D

I_3^- : $V = (3 \times 7) + 1 = 22e^-$

AB_2E_3

linear & non-polar

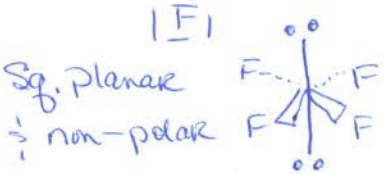
XeF_4

$V = 8 + 4(7) = 36e^-$

-32

$4e^-$

AB_4E_2



Sq. planar & non-polar

ORANGE

Q#1

6

1 1

2 2

3 3

4 4

5 5

6 ●

7 7

Q#2

5

1 1

2 2

3 3

4 4

5 ●

6 6

Answer to Question#1: A sol'n was prepared by dissolving 0.3865 g $K_2Cr_2O_7$ in water within a 100.0 mL volumetric flask. An iron sample of mass 0.700 g required 17.70 mL of the $K_2Cr_2O_7$ sol'n to reach the end point. How many moles of $FeCl_2$ were in the sample? What is the mass percent of iron in this sample?

$$6FeCl_2(aq) + K_2Cr_2O_7(aq) + 14HCl(aq) \rightarrow 6FeCl_3(aq) + 2CrCl_3(aq) + 2KCl(aq) + 7H_2O(l)$$

MM: 126.74 294.20 36.46 162.19 158.35 74.55 18.02 g/mol

Solution:

$n(K_2C_2O_4) = 0.3865\ g \times 1\ mol/294.20\ g = 0.001313_7$ or $\mathbf{1.313_7\times10^{-3}}$ moles ✓

$[K_2C_2O_4] = 1.313_7\times10^{-3}\ mol/100.0\ mL \times 1000\ mL/1\ L = 0.01313_7\ M$ or $\mathbf{1.313_7\times10^{-2}}$ M ✓

Reaction:

$n(K_2C_2O_4)$ used $= 1.313_7\times10^{-2}\ mol/L \times 17.70\ mL \times 1L/1000\ mL =$ **$2.325_3\times10^{-4}$ moles** ✓

(0.0002325_3 moles)

$n(FeCl_2)$ present $= 2.325_3\times10^{-4}\ mol\ K_2C_2O_4 \times 6\ mol\ FeCl_2/1\ mol\ K_2C_2O_4 =$ **$1.395_2\times10^{-3}$ moles** ✓

(0.001395_2 moles)

*If $n(FeCl_2) = 0.007882$ mol – didn't include dilution → 2 pts out of 4 (see below).

n_{Fe} present $= 1.395_2\times10^{-3}\ mol\ FeCl_2 \times 1\ mol\ Fe/1\ mol\ FeCl_2 =$ **$1.395_2\times10^{-3}$ moles**

mass Fe $= 1.395_2\times10^{-2}$ moles Fe $\times$ 55.84 g/1 mol = **0.07790_7 g** ✓

6 /6

% by mass of Fe $= (0.07790_7\ g / 0.700\ g) \times 100\% =$ **11.1%** ✓

*If $n(FeCl_2) = 0.007882$ mol used, would get 62.9% → overall 4/6

If $n(FeCl_2) = 3.876\times10^{-5}$ mol, ÷ 6 and if final answer is 0.309% → 5/6

Answer to Qu#2: 2 pts each; -1 for each mistake (*e.g.*, charges, phases, brackets & species).

soluble *soluble* *insoluble* *soluble*

(i) $NiI_2(aq) + Pb(NO_3)_2(aq) \rightarrow PbI_2(s) + Ni(NO_3)_2(aq)$

$\cancel{Ni^{2+}}(aq) + 2I^-(aq) + Pb^{2+}(aq) + \cancel{2NO_3^-}(aq) \rightarrow PbI_2(s) + \cancel{Ni^{2+}}(aq) + \cancel{2NO_3^-}(aq)$

5 /5

NIE: $\mathbf{Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)}$ ✓✓

(Next part is based on Expt#2)

soluble-strong acid ***insoluble*** *soluble* *reacts further*

(ii) $2HNO_3(aq) + CaCO_3(s) \rightarrow Ca(NO_3)_2(aq) + H_2CO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

$2H^+(aq) + \cancel{2NO_3^-}(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + \cancel{2NO_3^-}(aq) + H_2O(l) + CO_2(g)$

NIE: $\mathbf{2H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)}$ ✓✓✓

If: $2H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2CO_3(aq)$ **2 pt**

If: $CaCO_3(s) \rightarrow Ca^{2+}(aq) + CO_3^-(aq)$ **1 pt**

Turn over for next quest

ORANGE

Q#3
1 1
2 2
3 3
4 ●
5 5

Answer to Question #3: Hydrochloric acid reacts with aluminum to form aluminum chloride and hydrogen, i.e.,

$$6HCl_{(aq)} + 2Al_{(s)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

If 0.9687 moles of hydrochloric acid reacts with 0.6295 moles of aluminum metal, how many litres of hydrogen gas are produced at 100.0°C and 1.00 atm?

$n(H_2)$ via HCl = 0.9687 mol HCl × 3 mol H_2/6 mol HCl = **0.4843_5 mol** H_2 ✓ OR 0.9687 mol HCl/6 = 0.1614_5

$n(H_2)$ via Al = 0.6295 mol Al × 3 mol H_2/2 mol Al = **0.9442_5 mol** H_2 ✓ OR 0.6295 mol Al/2 = 0.3147_5

4 /4

HCl is the limiting Reagent – must compare the 2 numbers in some manner to determine LR!

n = 0.4843_5 moles H_2 T = 100.0°C = 373.15 K P = 1.00 atm = 101.3 kPa

V = nRT/P = (0.4843_5 moles H_2)(0.08206 atm·L·mol^{-1}·K^{-1})(373.15 K)/1 atm

OR ✓ **(substitution)**

V = nRT/P = (0.4843_5 moles H_2)(8.314 kPa·L·mol^{-1}·K^{-1})(373.15 K)/101.3 kPa

V = 14.8 L ✓

If V = 13.0 L, used Al (0.5296 mol) instead → **2 pts only because didn't evaluate LR**

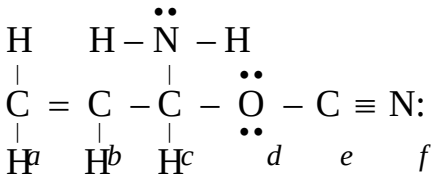
If V = 2.5 L, used 0.1614_5 × 3/**6** = 0.08072_5 moles H_2, but calculated V correctly → 3 pts

Answers to Question #4:

Q#4
5
1 1
2 2
3 3
4 4
5 ●
6 6

The molecule has **12** sigma & **3** pi bonds. ✓ ✓

The O_d - C_e - N_f bond angle is **180°**. ✓



5 /5

The type of orbitals that best describe the bond between atoms (b) and (c) are **sp^2 – sp^3** ✓✓