AP Chemistry FRQ 2018 Draft Answers and Projected Points
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1. (a)

The oxidation number of Cl is +1	1 point for the correct oxidation number

(b)

$0.500\ M\ Na_2S_2O_3 \times 0.10000\ L = 0.0500\ mol\ Na_2S_2O_3$ $0.0500\ mol\ Na_2S_2O_3 \times \frac{158.1\ g}{1\ mol} = 7.91\ g\ Na_2S_2O_3$	1 point for the correct number of moles $Na_2S_2O_3$ (may be implicit) 1 point for the correct mass of $Na_2S_2O_3$

(c)

$0.500\ M\ \times 0.00500\ L = 0.00250\ mol\ of\ each\ reactant$ The limiting reactant is NaOCl*(aq)*. With equimolar starting amounts, the NaOCl*(aq)* will be consumed first due to the reaction ratio in which 4 moles of NaOCl*(aq)* are consumed for every 1 mole of $Na_2S_2O_3$*(aq)* and every 2 moles of NaOH*(aq)*.	1 point for identifying the limiting reactant with proper justification.

(d)

$\Delta T = T_f - T_i = 32.5°C - 20.0°C = 12.5°C$	1 point for the correct temperature to three significant figures

(e)(i)

$q = cm\Delta T = \left(3.94 \frac{J}{g \cdot °C}\right)(15.21\ g)(12.5°C) = 749\ J$	1 point for the correct magnitude of energy

(e)(ii)

$749\ J \times \frac{1\ kJ}{1000\ J} = 0.749\ kJ$ $\frac{0.749\ kJ}{0.0025\ mol\ NaOCl} = 300. \frac{kJ}{1\ mol\ NaOCl}$ $300. \frac{kJ}{1\ mol\ NaOCl} \times \frac{4\ mol\ NaOCl}{1\ mol_{rxn}} = -1.20\ \times 10^3 kJ/mol_{rxn}$	1 point for calculating the amount of energy released for every 1 mole of NaOCl 1 point for the correct enthalpy value with the correct algebraic sign taking in to account the reaction ratio

(f)

Enthalpy is given in units of per mole of reaction. The amount of energy released each time the reaction runs will not change even if the total amount of energy released is different.	1 point for the proper explanation

(g)

$S_2O_3^{2-}$*(aq)* + $4OCl^-$*(aq)* + $2OH^-$*(aq)* → $2SO_4^{2-}$*(aq)* + $4Cl^-$*(aq)* + H_2O*(l)*	1 point for the correct equation

2. (a)

Diagram should show 8 molecules of NO and 2 molecules of O_2	1 point for the correct diagram

(b)(i)

$K = e^{-\frac{\Delta G^o}{RT}} = e^{-\frac{870\ J}{(8.314\frac{J}{mol\cdot K})(298\ K)}} = 0.70$	1 point for proper substitution in to the correct equation 1 point for the correct value of K

(b)(ii)

No. For $P_{N_2O_3} = 1$ the reaction would have to go to completion. Given that $K < 1$, the reaction does not go to completion, so the partial pressure of $N_2O_3(g)$ will be less than 1.	1 point for an explanation consistent with the value of K calculated in part (b)(i)

(c)

Disagree with the hypothesis. Increasing the temperature will favor the endothermic direction of the reaction. Since the forward reaction is exothermic, then the reverse reaction is endothermic. Increasing the temperature will increase the rate of the reverse reaction more than the rate of the forward reaction, decreasing the amount of $N_2O_3(g)$.	1 point for disagreeing with an appropriate justification

(d)(i)

	1 point for a properly drawn Lewis structure

(d)(ii)

sp^2	1 point for a hybridization consistent with the Lewis diagram in part (d)(i)

(e)(i)

20.0 mL of 0.100 *M* KOH required to reach the equivalence point of the titration $0.100\ M\ KOH \times 0.0200\ L = 0.00200\ mol\ KOH$ 0.00200 mol KOH = 0.00200 mol HNO_2 $M = \frac{0.00200\ mol}{0.100\ L} = 0.0200\ M$	1 point for the correct molarity

(e)(ii)

3.3	1 point for a pK_a greater than 3.0 but less than 3.5

(f)

$NO_2^-(aq)$ is present in the higher concentration. After 15 mL of KOH(aq) has been added the reaction has passed the half-equivalence point so $[NO_2^-] > [HNO_2]$	1 point for the correct conclusion with proper justification

3. (a)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ OR $[Ar]3d^6$	1 point for the correct electron configuration

(b)

The radius of Fe^{2+} is greater than the radius of Fe^{3+} due to the additional electron-electron repulsions between the two paired d-orbital electrons in Fe^{2+}.	1 point for a correct justification

(c)

Fe^{3+} ions interact more strongly with water molecules because they are more charged than Fe^{2+} ions. More charge increases electrostatic attraction. OR Fe^{3+} ions interact more strongly with water molecules because they have a smaller ionic radius and can get closer to water molecules. A shorter distance between interacting species increases electrostatic attraction.	1 point for identifying one reason with a proper justification

(d)

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$	1 point is earned for the correct equation

(e)

$0.0350\ M \times 0.01748\ L = 6.12 \times 10^{-4} mol\ MnO_4^-$ $6.12 \times 10^{-4} mol\ MnO_4^- \times \frac{5\ mol\ Fe^{2+}}{1\ mol\ MnO_4^-} = 3.06 \times 10^{-3}$ $[Fe^{2+}] = \frac{3.06 \times 10^{-3}\ mol\ Fe^{2+}}{0.0100\ L} = 0.306\ M$	1 point is earned for the moles of Fe^{2+} (may be implicit) 1 point is earned for the correct concentration of Fe^{2+}

(f)

A 25 mL volumetric flask is designed to measure only 1 volume (25 mL) of solution and is not suited for distributing smaller volumes.	1 point for the correct explanation

(g)

$7.531\ g\ Fe_2O_3 \times \frac{1\ mol}{159.7\ g} \times \frac{2\ mol\ Fe}{1\ mol\ Fe_2O_3} = 0.09431\ mol\ Fe$	1 point for the correct number of moles

(h)

$0.09431\ mol\ Fe \times \frac{55.85\ g\ Fe}{1\ mol\ Fe} = 5.268\ g\ Fe$ $\frac{5.268\ g\ Fe}{6.724\ g\ sample} \times 100 = 78.34\%$	1 point is earned for the correct percentage

(i)

FeO has a higher mass percent of oxygen than Fe_2O_3. Therefore, if FeO was present the calculated mass percent in (h) would be less than the actual mass percent of iron in the mixture.	1 point for the correct explanation

4. (a)

CS_2 experiences London Dispersion Forces (LDFs) between its molecules and COS experiences both dipole-dipole interactions and LDFs. The sum of the strengths of the intermolecular forces in CS_2 must be greater than that in COS. This is due to the greater number of electrons in CS_2 which leads to a larger and more polarizable electron cloud, leading to stronger LDFs. Therefore, these IMFs between CS_2 molecules require more energy to overcome and the boiling point is higher.	1 point for the proper identification of intermolecular forces in each compound 1 point for a valid explanation

(b)

$10.0\ g\ CS_2 \times \frac{1\ mol}{76.13\ g} = 0.131\ mol$ $P = \frac{nRT}{V} = \frac{(0.131\ mol)(0.08206\ \frac{atm \cdot L}{mol \cdot K})(325\ K)}{5.0\ L} = 0.70\ atm$	1 point for the number of moles of CS_2 1 point for the correct pressure

5. (a)

Figure 1 is a more accurate representation because only 1 of the HF molecules ionizes compared to 8 in Figure 2, which is consistent with HF being a weak acid.	1 point for the correct explanation

(b)

$13.0\ \% = \frac{[H^+]}{[0.0350\ M]} \times 100$ $[H^+] = 0.00455\ M$ $[H^+] = [F^-]$ $K_a = \frac{[H^+][F^-]}{[HF]} = \frac{[0.00455\ M][0.00455\ M]}{[0.0350\ M - 0.00455\ M]} = 6.79 \times 10^{-4}$	1 point for the correct $[H^+]$ 1 point for the correct value of K_a

(c)

The percent ionization will increase. When the solution is diluted, the concentration of all species will decrease by half. $Q = \frac{\frac{1}{2}[0.00455\ M]\frac{1}{2}[0.00455\ M]}{\frac{1}{2}[0.0350\ M]} = 2.96 \times 10^{-4}$ Since Q < K so more HF will dissociate until equilibrium is restored.	1 point for a valid selection with proper justification

6. (a)

The cell is missing a salt bridge. The salt bridge is necessary to allow a path for ions to flow to maintain charge balance between each half-cell neutral.	1 point for the identification of the salt bridge with proper explanation for its use

(b)(i)

$E^o_{cell} = E^o_{red} + E^o_{ox}$ $1.54\ V = 0.80V + E^o_{ox}$ $E^o_{ox} = 0.74\ V \therefore E^o_{red} = -0.74\ V$	1 point for the correct value of E^o

(b)(ii)

$3Ag^+(aq) + Cr(s) \rightarrow 3Ag(s) + Cr^{3+}(aq)$	1 point for the balanced net-ionic equation

(b)(iii)

$\Delta G^o = -nFE^o = -(3\ mol\ e^-)(96485 \frac{C}{mol\ e^-})(1.54\ V)$ $\Delta G^o = -446{,}000\ J/mol_{rxn}$	1 point for the correct value of ΔG^o

7. (a)

The element is nitrogen.	1 point for the correct element

(b)

$t_{\frac{1}{2}} = \frac{0.693}{k}$ $10.\ min = \frac{0.693}{k}$ $k = 0.069\ min^{-1}$	1 point for the correct value of *k* 1 point for the units

(c)

1 atom of the original isotope would remain after 60 minutes.

Atoms of the Original Isotope Present	Time Elapsed (min)
64	0
32	10
16	20
8	30
4	40
2	50
1	60

1 point for the proper amount of time with work showing how the number was obtained.