2022 Released FRQ Draft Answers

Question 1

(a) ((0.300)/(152.15))(138.12) = 0.272 mols

(b) Yes. If some of the solid dissolved, then less solid would be collected, resulting in a yield of less than 100%.

(I'm a bit concerned about this, maybe such a small washing might not dissolve 13%? It's a little ambiguous for me.)

(c) To increase the temperature of the crystals to their melting point;

q = m c ΔT = (0.105)(1.17)(159-25) = 16.5 J

To melt the crystals completely;

q = (27.1)(0.105/138.12) = 0.0206 kJ

Total energy required = (16.5/1000) + 0.0206 = 0.0371 kJ

(d) Salicylic acid has two potential sites for hydrogen bonding as opposed to methyl salicylate's one. This allows for a greater degree (and strength) of intermolecular forces, and a greater amount of energy being required to melt the crystals in salicylic acid.

(e) 3.00 (assuming the acid to be weak, pH = pKa at the half-equivalence point)

(f) Conjugate base. Halfway to equivalence point (5 mL of NaOH added) the amounts of weak acid and conjugate base are equal. Since a pH of 4.00 is past the half-equivalence point, more than half of the acid has been reacted, and more than half of the conjugate base has been produced.

(g) pKa = - log Ka = 4.2

(h) Start the curve at 3.11 on the y -axis

Follow the approx. same shape, but above the original line, showing a point at (5.00, 4.20)

Equivalence point at the same value on the x-axis (10 mL of NaOH added)

Equivalence point at a higher value on the y-axis (as benzoic is a weaker acid it will have a stronger conjugate base than salicylic)

Finish in the same place (tracing the original line) after the equivalence point

Question 2

(a) Reduced. H (+1) to H (0), i.e., a gain of electrons.

(b) Triple bond between the atoms, and each atom with one lone pair.

(c) (i) $\Delta S° = (((2)(131)) + (198)) – (240.) = 220.$ J/Kmol

(ii) $\Delta G° = (90.0) – (375)(220/1000) = 7.50$ kJ/mol

(d) (3/10)(12.0) = 3.60 atm

(e) $Kp = (ppH_2)^2(ppCO)/(ppCH_3OH)$

(f) $Kp = (8.4)^2(4.2)/(2.7) = 110$

(g) All of the partial pressures half, meaning $Q = (4.2)^2(2.1)/(1.35) = 27$

Since Q is less than K, the reaction shifts forward, and the number of moles of CH_3OH decreases as equilibrium is re-established.

Question 3

(a) $1s^2 2s^2 2p^6 3s^2 3p^1$

(b) Al^{3+} has lost the 3rd shell valence electrons, making the radius of the species smaller, where the second shell is the now the outer shell.

(c) 2. Carefully transfer the solid $AgNO_3$ to the volumetric flask

3. Add a small amount of distilled water to the flask, with gentle swirling, in order to dissolve the solid completely

4. Make up to the mark by carefully adding distilled water to the flask

(d) The right beaker should contain $2Al^{3+}_{(aq)}$ ions, $2Ag^{+}_{(aq)}$ ions, and $6Ag_{(s)}$ atoms, in addition to the $2Al_{(s)}$ atoms already shown.

(e) $E° = +1.66 + 0.80 = +2.46$ V

(f) Negative. $\Delta G° = - n F E°$, where n and F are positive numbers. The positive value of E° makes $\Delta G°$ negative. Also, a positive E° suggests a thermodynamically favorable reaction which is paired with a negative $\Delta G°$ value.

(g) At equilibrium, E° = 0.00 V, and $\Delta G° = 0$.

Question 4

(a) (1.0)(0.0016) = 0.0016 g

(0.0016)/(51.48) = 3.1 x 10^{-5} mols

(b) NH_2Cl has the ability to exhibit hydrogen bonding, which will allow it to hydrogen bond with water and make it extremely soluble. It also exhibits dipole-dipole and London dispersion forces.

NCl_3 exhibits dipole-dipole and London dispersion forces., but cannot hydrogen bond with water, so is less soluble.

(There is the possibility to say that NCl_3 can H-bond with water, BUT I hope that is not required since it opens the need for other explanations to distinguish between the two compounds – see blog post)

(c) ((15.0)/(120.36))(32.9) = 4.10 kJ

Question 5

(a) $k = 0.693/ t_{½} = 0.693/1.67 \text{ hr} = 0.415 \text{ hr}^{-1}$

(b) Step 1. The slow, rate determining step has a stoichiometric value of 1 for N_2O_5 which is consistent with the rate law having an order of 1 for N_2O_5.

(c) k would remain the same. Rate constants are temperature dependent.

Question 6

(a) 525 nm

(b) (i) 92.0 mL

(ii) $(0.1000)(1.68 \times 10^{-3}) = (2.40 \times 10^{-3})(x)$

$x = 0.0700 \text{ L} = 70.0 \text{ mL}$

(iii) Step 3. Failing to rinse the cuvette with the standard solution before filling, will leave water in the cuvette and inadvertently dilute the standard solution, giving a smaller absorbance than expected.

Question 7

(a) sp^2

(b) (i) $Ksp = [Ag^+]^2[C_2O_4^{2-}]$

(ii) $5.40 \times 10^{-12} = 4x^3$

$x = 1.11 \times 10^{-4}$ M

(iii) $H^+_{(aq)} + C_2O_4^{2-}{}_{(aq)} \rightarrow HC_2O_4^-{}_{(aq)}$

or

$2H^+_{(aq)} + C_2O_4^{2-}{}_{(aq)} \rightarrow H_2C_2O_{4(aq)}$