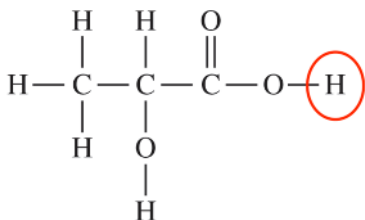


Question 1

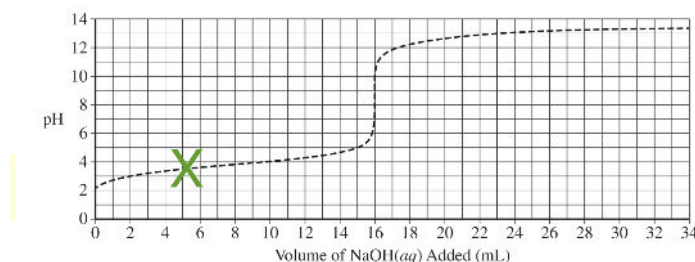
(a)



(b) $(10.22 \text{ g}/40.00 \text{ g/mol})/(0.500 \text{ L}) = 0.511 \text{ M}$

(c) 4.0 (The pH halfway to the equivalence point, i.e., at 8 mL of NaOH added)

(d) (i)



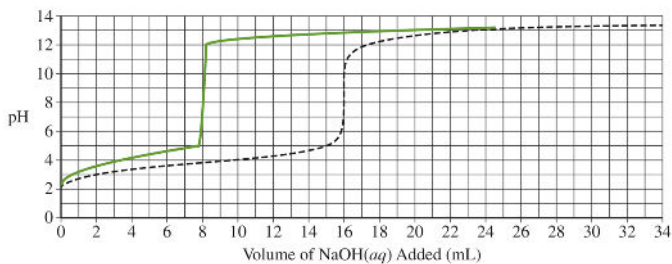
(ii) $\text{pH} = \text{pK}_a + \log \left(\frac{[\text{C}_3\text{H}_5\text{O}_3^-]}{[\text{C}_3\text{H}_6\text{O}_3]} \right) = 4.0 + \log (2/4) = 3.699.$

(As long as no calculation is required, any point beyond 0 mL of NaOH added and 8 mL of NaOH added is likely to be accepted).

Alternative answer is to simply say that $[\text{C}_3\text{H}_5\text{O}_3^-] < [\text{C}_3\text{H}_6\text{O}_3]$ so the titration must be at a point prior to halfway to the equivalence point, i.e., before 8 mL.

(As long as no calculation is required, any point beyond 0 mL of NaOH added and 8 mL of NaOH added, with the explanation above, is likely to be accepted).

(iii)



(e) (i) $\Delta T = 23.2 - 20.0 = 3.2 \text{ }^\circ\text{C}$

$$q = m c \Delta T = (200.0 \text{ g})(4.2 \text{ J/g}^\circ\text{C})(3.2 \text{ }^\circ\text{C}) = 2700 \text{ J}$$

(ii) Moles = $(100.0/1000)(0.500) = 0.0500 \text{ mols}$

Exothermic reaction because of the increase in temperature means a negative sign for the enthalpy change.

$$\Delta H = - (2700 \text{ J}/1000 \text{ kJ/J})/(0.0500 \text{ mol}_{\text{rxn}}) = - 54 \text{ kJ/mol}_{\text{rxn}}$$

(iii) I agree. If energy is lost to the surrounding air, the temperature of the solution would not increase as much, giving a smaller magnitude for ΔT , thus a smaller magnitude q , thus a smaller magnitude ΔH_{rxn} .

Question 2

(a) (i) $(0.0114 \text{ mol})(44.01 \text{ g/mol}) = 0.502 \text{ g}$

(ii) $P V = n R T = (1.25 \text{ atm})(V) = (0.0114 \text{ mol})(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(293 \text{ K})$
 $V = 0.219 \text{ L}$

(b) (i) It increases.

(ii) Shorter. Increased surface area means an increased number of collisions between the reactant particles and therefore a faster rate of reaction.

(iii) Equal to. Same number of moles are used.

(c) $(1.543 \text{ g})/(116.072 \text{ gmol}^{-1}) = 0.01329 \text{ mol of H}_2\text{C}_2\text{H}_2\text{O}_4$

$(1.251 \text{ g})/(84.008 \text{ gmol}^{-1}) = 0.01489 \text{ mol of NaHCO}_3$

Since the $\text{H}_2\text{C}_2\text{H}_2\text{O}_4$ and NaHCO_3 react in a 1:2 ratio, there is insufficient NaHCO_3 to react with all the $\text{H}_2\text{C}_2\text{H}_2\text{O}_4$, so NaHCO_3 is the limiting reactant.

(d) The products (2 mol (g), 2 mol (l) and 1 mol (aq)) are more dispersed (more disordered with more microstates) than the reactants, i.e., have greater entropy than the reactants (3 mol (aq)).

(e) I disagree. At low temperatures, the term $T\Delta S^\circ$ in the equation $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$, may be insufficiently large in magnitude when subtracted from a positive ΔH° , to create the negative ΔG° required for a thermodynamically favored reaction.

(f) $\text{pK}_a = -\log K_a = -\log (8.5 \times 10^{-7}) = 6.07$

(g) Call the ratio X

$$\text{pH} = \text{pK}_a + \log X$$

$$7.00 = 6.07 + \log X$$

$$X = 8.5$$



Question 3

(a) 0, +1

- (b) (i) Substitutional alloys occur when atoms of one radius are replaced by atoms of another metal of approximately the same (or a similar) radius. Ag and Cu have radii that are very similar.
- (ii) Ag's valence electrons are in the 5th energy level; copper's are in the 4th. Since the distance from the nucleus of the valence electrons in Ag is greater than that of Cu, the Coulombic attraction is less in Ag, and therefore, on average, electrons in the 5th energy level are further from the nucleus than those in the 4th.

(I don't think that Coulombic attraction is really required to explain the difference in size. Obviously since the question asks this, there will be a likely requirement to include it, but I feel as though valence shells 5 versus 4, and their relative average distance from the nucleus should be sufficient. Is that because of Coulombic attraction? Sure, but all this does is cement the CB's obsession with it. In years past, an understanding that electrons in higher energy levels are further (on average) from the nucleus has been entirely sufficient, i.e., and answer like this would score full credit.

Ag's valence electrons are in the 5th energy level; copper's are in the 4th. On average, electrons in the 5th energy level are further from the nucleus than those in the 4th.)

(c) Mass of Ag₂S = 409.21 – 398.94 = 10.27 g

Since 1 mole of Ag₂S contains 2 mols of Ag

Moles of Ag = (2)(10.27 g)/(247.80 g mol⁻¹) = 0.08289 mols

(d) (i) $4\text{Rh}^{3+}_{(\text{aq})} + 6\text{H}_2\text{O}_{(\text{l})} \rightarrow 4\text{Rh}_{(\text{s})} + 3\text{O}_{2(\text{g})} + 12\text{H}^{+}_{(\text{aq})}$

(ii) $+0.80 \text{ V} + (-1.23 \text{ V}) = -0.43 \text{ V}$

(iii) Negative voltage means this is a reaction with a positive ΔG° , i.e., is not thermodynamically favored, that must be driven by an external voltage.

(e) Moles of Rh = $(2.8 \text{ g}) / (102.91 \text{ g mol}^{-1})$

Since 3 moles of e^- are required per mol of Rh, $(\text{Rh}^{3+}_{(\text{aq})} + 3e^- \rightarrow \text{Rh}_{(\text{s})})$, then,

Moles of e^- = $(3)((2.8 \text{ g}) / (102.91 \text{ g mol}^{-1}))$

Total charge = $(3)((2.8 \text{ g}) / (102.91 \text{ g mol}^{-1}))(96485 \text{ C/mol of } e^-)$

$q = I/t = (3)((2.8 \text{ g}) / (102.91 \text{ g mol}^{-1}))(96485 \text{ C/mol of } e^-) = (2.0 \text{ C/s}) / (t)$

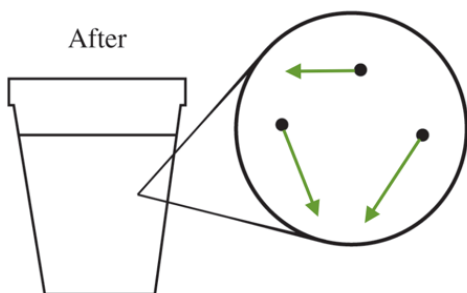
$t = 3.9 \times 10^3 \text{ s}$



Question 4

(a) 38.5 °C

(b)



(c) $\Delta T = 100.0\text{ }^{\circ}\text{C} - 38.5\text{ }^{\circ}\text{C} = 61.5\text{ }^{\circ}\text{C}$

Energy lost by metal cube = $q = m c \Delta T = (98.1\text{ g})(c)(61.5\text{ }^{\circ}\text{C}) = 2940\text{ J}$

$c = 0.487\text{ J/g}^{\circ}\text{C}$

(d) For Al,

$q = m c \Delta T = (98.1\text{ g})(0.897\text{ J/g}^{\circ}\text{C})(\Delta T) = 2940\text{ J}$

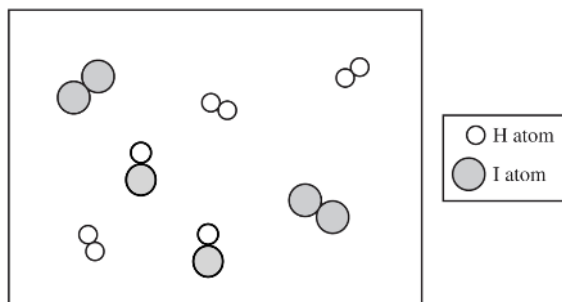
$\Delta T = 33.4\text{ }^{\circ}\text{C}$, so the temperature change is of a smaller magnitude.

Question 5

(a) $K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$

(b) (i) $0.67 = \frac{[\text{HI}]^2}{(3)(2)}$

$[\text{HI}] = 2$



- (ii) The reaction has shifted to produce more HI. Since the forward reaction is exothermic, reducing the temperature could cause the change. Le Châtelier's principle states that equilibria will shift to oppose the external change imposed upon the system. Reducing the temperature will result in the equilibrium shifting in such a way as to raise the temperature. In an exothermic forward reaction this is achieved by shifting to the product side, producing more energy, and in turn producing more HI.
- (iii) Remain the same. Increasing the volume of the container reduces the pressure of all the gases. Since in the Q expression partial pressure squared appears in the numerator, and *effectively* partial pressure squared appears in the denominator, the value of Q does not change, and no shift in the equilibrium position is required to re-establish the K value.

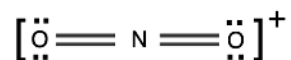
Question 6

(a) A plot of $1/[\text{NO}_2]$ is a linear which is indicative of a second order reaction.

(b) From the balanced equation, the ratio of disappearance of NO_2 to the appearance of O_2 is 2:1.

$$(6.52 \times 10^{-7} \text{ M/s})/2 = 3.26 \times 10^{-7} \text{ M/s}$$

(c) (i)



(ii) Agree. NO_2 has three electron domains around the central atom so bond angles of approx. 120° , whereas NO_2^+ has two electron domains around the central atom so will have a bond angle of approx. 180° .



Question 7

(a) $(0.100 \text{ L})(0.340 \text{ mol/L})(58.44 \text{ g/mol}) = 1.99 \text{ g}$

(b) 2. Without spilling, carefully transfer all the solid to the volumetric flask, and add anywhere between 10 and 75 mL of distilled water.

4. Make up to the mark, using the pipet for precision near the mark.

(c) Longer times result in larger separation, shorter in smaller separation so the second student would have a smaller separation.

I cannot imagine any of what follows is necessary, but it is a great way to illustrate how time makes a difference.

X and Y are currently separated by 0.4 cm

X has a Rf value of $1.1/2.5 = 0.44$

Y has a Rf value of $1.5/2.5 = 0.60$

Increasing the length of time increases the distance traveled by the solvent, i.e., makes the denominator larger. Using a distance of 3.0 cm rather than 2.5 cm, and knowing each component has a fixed Rf value, we find,

For X, distance traveled = $(3.0)(0.44) = 1.3$

For Y distance traveled = $(3.0)(0.60) = 1.8$

i.e., X and Y are now separated by 0.5 cm, a greater separation.