

Chemistry 1154 Fall 2011 test 3

Thursday, November 24, 2011

Time: 1 hour 50 minutes

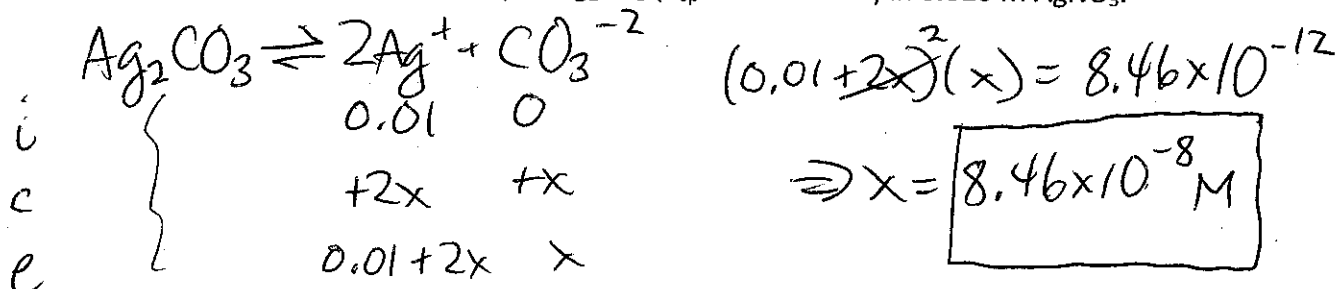
Name: ANSWERS

Student number: _____

This test consists of **nine** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete paper and, if you do not, obtain one from me **immediately**. There are **42** marks available. Good luck!

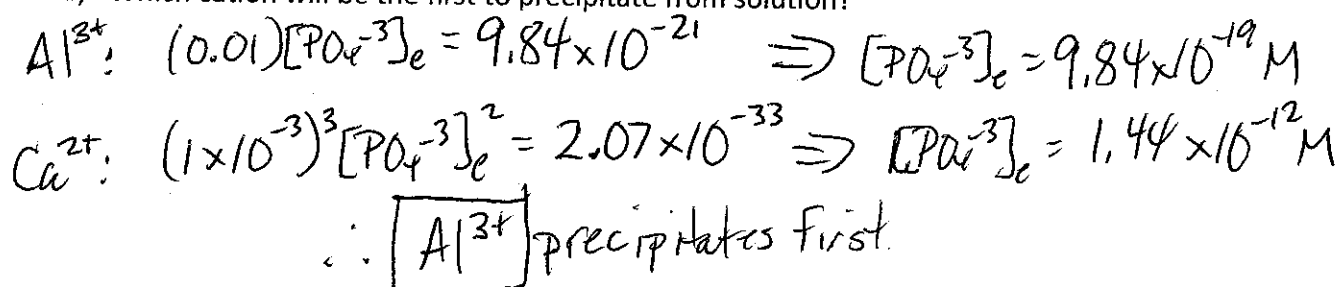
Note: Unless specifically stated otherwise, you may assume a temperature of 25°C for all questions.

- 1) [2 marks] Calculate the solubility of Ag_2CO_3 ($K_{sp} = 8.46 \times 10^{-12}$) in 0.010 M AgNO_3 .



- 2) [4 marks] A solution has $[\text{Al}^{3+}] = 0.010 \text{ M}$, and $[\text{Ca}^{2+}] = 1.0 \times 10^{-3} \text{ M}$. Solid Na_3PO_4 is slowly added to the solution. If the K_{sp} of AlPO_4 is 9.84×10^{-21} and of $\text{Ca}_3(\text{PO}_4)_2$ is 2.07×10^{-33} :

- a) Which cation will be the first to precipitate from solution?



- b) At the point of maximum separation, what percent of the ion from (a) will remain in solution?

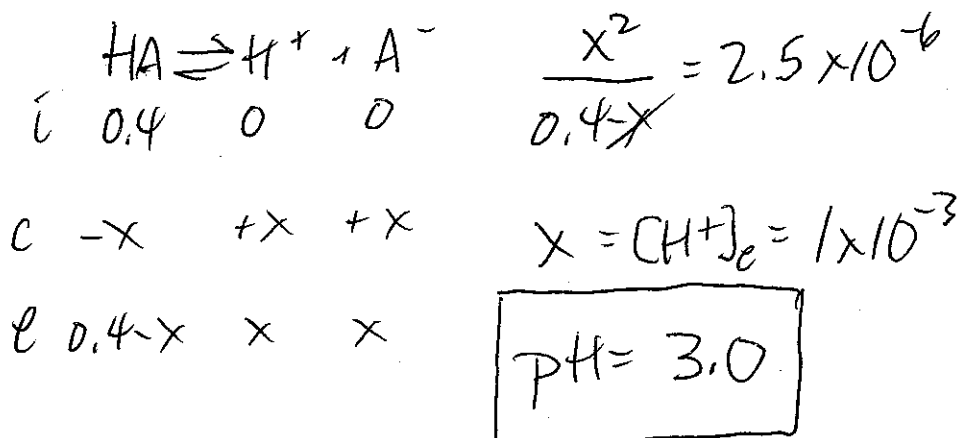
$$[\text{Al}^{3+}]_e (1.44 \times 10^{-12}) = 9.84 \times 10^{-21}$$

$$\Rightarrow [\text{Al}^{3+}]_e = 6.84 \times 10^{-9} \text{ M}$$

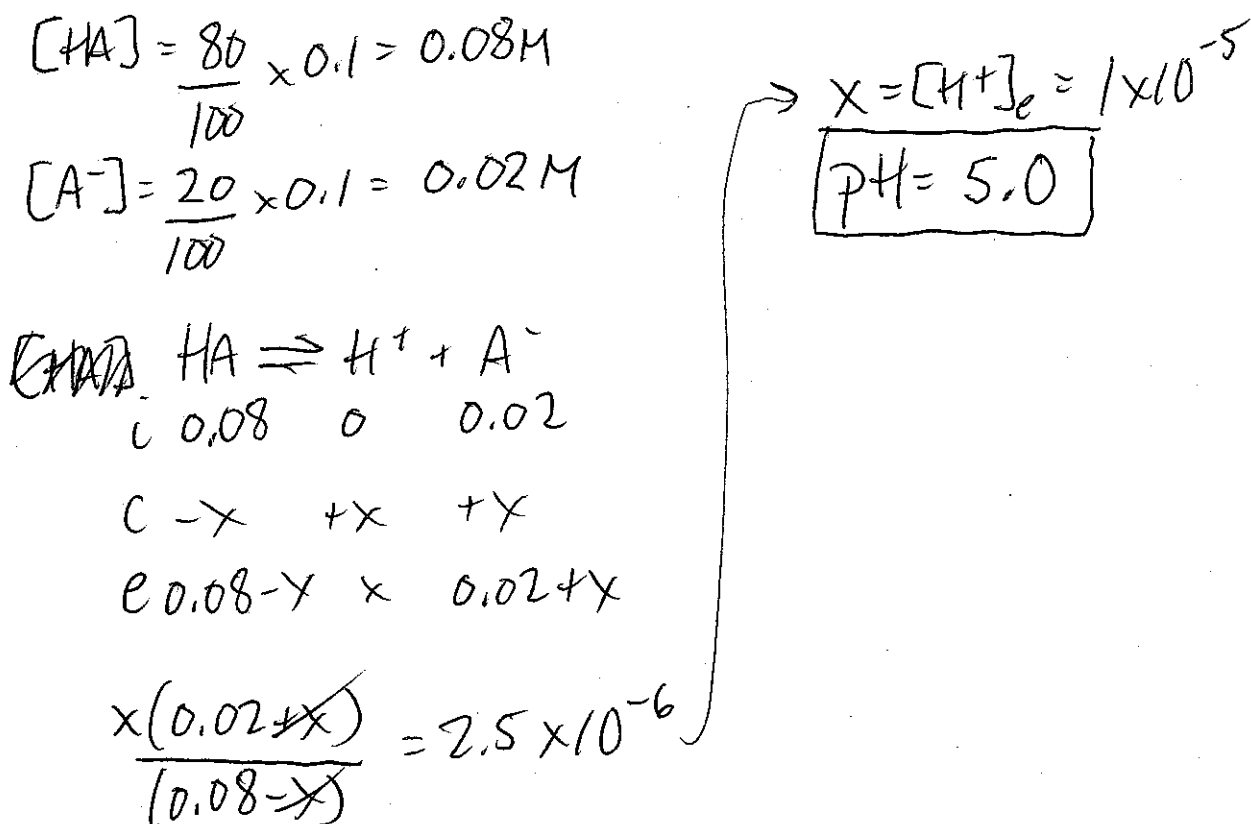
$$\frac{6.84 \times 10^{-9}}{0.01} \times 100 = \boxed{6.84 \times 10^{-5} \%}$$

3) [5 marks total] Calculate the pH of the following solutions. HA is a weak acid with $K_a = 2.5 \times 10^{-6}$

a) [2 marks] 0.40 M HA



b) [3 marks] 80.0 mL of 0.10 M HA mixed with 20.0 mL of 0.10 M KA

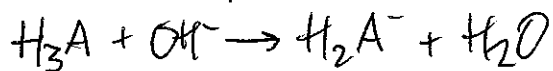


- 4) [5 marks total] Calculate the pH of the following solutions. H_3A is a weak acid with $pK_{a1} = 3.00$, $pK_{a2} = 7.00$, and $pK_{a3} = 11.00$

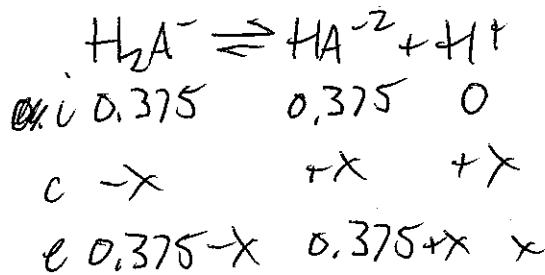
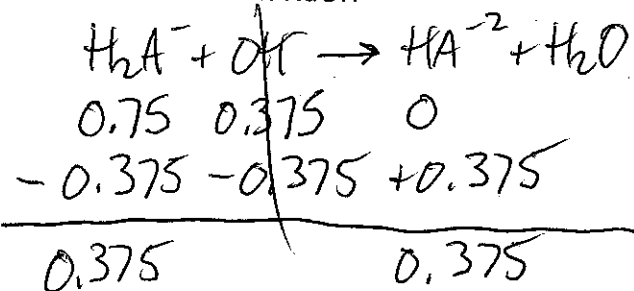
a) [3 marks] 10.00 mL of 3.00 M H_3A mixed with 30.00 mL of 1.50 M NaOH

$$[H_3A] = \frac{10}{40} \times 3 = 0.75 M$$

$$[OH^-] = \frac{30}{40} \times 1.5 = 1.125 M$$



0.75	1.125	0	
-0.75	-0.75	+0.75	
0	0.375	0.75	



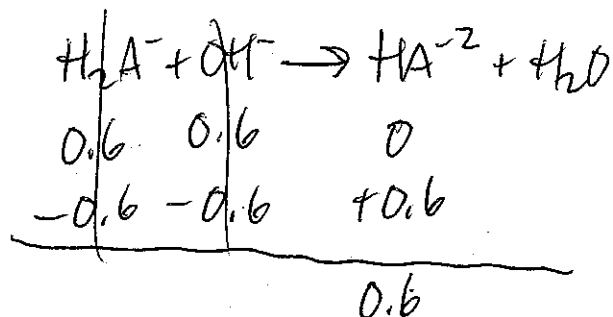
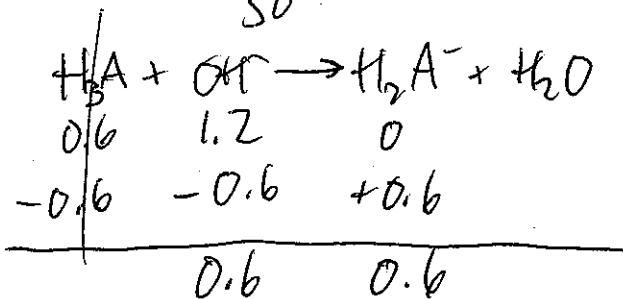
$$\frac{x(0.375+x)}{(0.375-x)} = 10^{-7} \quad x = [H^+] = 1 \times 10^{-7} M$$

pH = 7.0

b) [2 marks] 10.00 mL of 3.00 M H_3A mixed with 40.00 mL of 1.50 M NaOH

$$[H_3A] = \frac{10}{50} \times 3 M = 0.6 M$$

$$[OH^-] = \frac{40}{50} \times 1.5 M = 1.2 M$$



Amphiprotic: either gain 2nd proton or lose 3rd.

$$pH = \frac{1}{2}(pK_{a2} + pK_{a3}) = 9.0$$

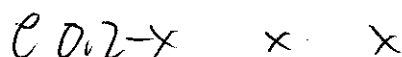
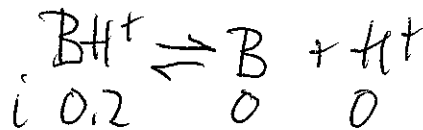
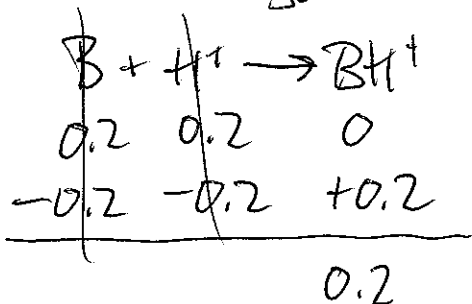
9.0

5) [6 marks total] Calculate the pH of the following solutions. B is a weak base with $K_b = 1.00 \times 10^{-5}$ at a temperature where $K_w = 1.0 \times 10^{-13}$.

a) [4 marks] 10.00 mL of 1.00 M B mixed with 40.00 mL of 0.250 M HNO_3 .

$$[B] = \frac{10}{50} \times 1.00 = 0.2 \text{ M}$$

$$[H^+] = \frac{40}{50} \times 0.25 \text{ M} = 0.2 \text{ M}$$



$$\frac{x^2}{0.2-x} = \frac{1 \times 10^{-13}}{1 \times 10^{-5}} = 1 \times 10^{-8}$$

$$\Rightarrow x = [H^+]_e = 4.47 \times 10^{-5}$$

$$\boxed{\text{pH} = 4.35}$$

b) [2 marks] 10.00 mL of 1.00 M B mixed with 50.00 mL of 0.250 M HNO_3 .

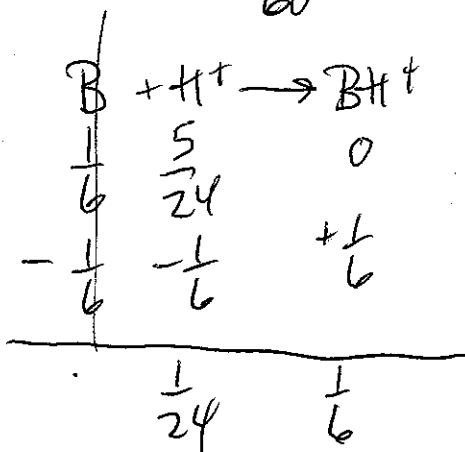
$$[B] = \frac{10}{60} \times 1.00 = \frac{1}{6} \text{ M}$$

$$[H^+] = \frac{50}{60} \times 0.25 \text{ M} = \frac{5}{24} \text{ M}$$

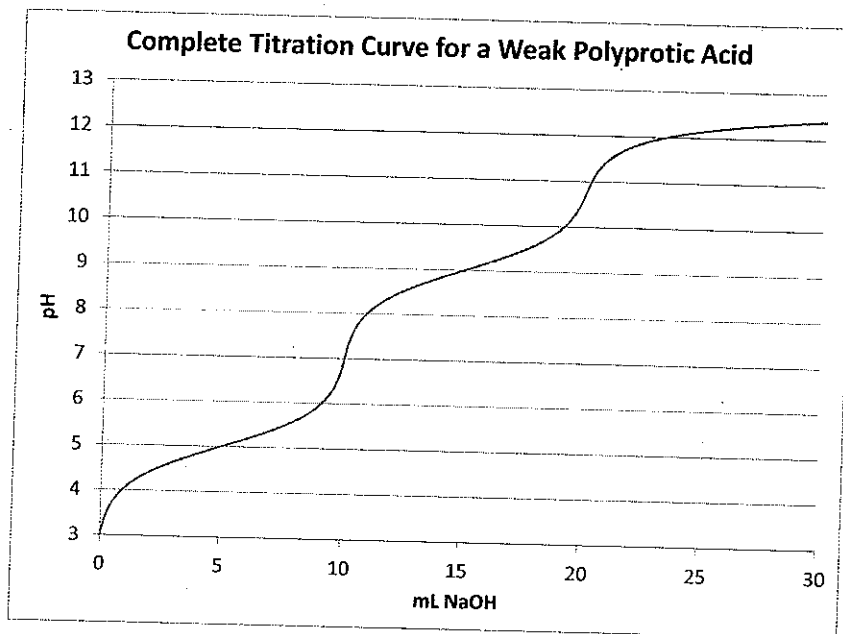
$$[H^+]_e = \frac{1}{24} \text{ M}$$

$$\text{pH} = \log(24)$$

$$= \boxed{1.38}$$



- 6) [3 marks] The following diagram is the complete titration curve for a weak polyprotic acid with a strong base.



- a) How many acidic protons does the weak polyprotic acid have?

2

- b) What are the pK_a values for the weak polyprotic acid?

5 + 9

- c) What would be a good pK_{ind} for an indicator to be used in this titration? How do you know?

pH @ 1st EP is $\frac{1}{2}(5+9)=7$, so use $pK_{ind}=7$.

7) [4 marks total] A 10.00-mL aliquot of 1.00×10^{-2} M HCl is to be titrated with 1.10×10^{-3} M NaOH. An indicator with a $pK_{ind} = 10.00$ is to be used.

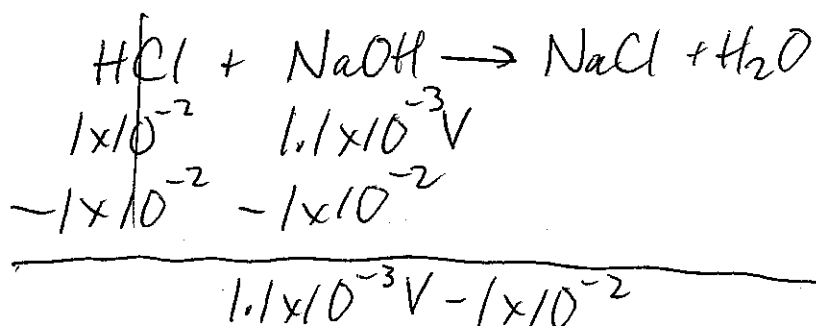
a) [3 marks] How many mL of NaOH will be required to reach the end point?

$$V = \text{mL NaOH}$$

$$1 \times 10^{-3} \text{ moles} \times 10 \text{ mL} = 1 \times 10^{-2} \text{ mmol HCl}$$

$$\therefore 1.1 \times 10^{-3} \times V = \text{mmol NaOH}$$

$pK_{ind} = 10$ means
base in excess.
 $[OH^-]_e = 1 \times 10^{-4}$



$$[OH^-]_e = \frac{1.1 \times 10^{-3} V - 1 \times 10^{-2}}{10 + V} = 1 \times 10^{-4}$$

$$\frac{11V - 100}{10 + V} = 1$$

$$\begin{aligned} \rightarrow 11V - 100 &= 10 + V \\ 10V &= 110 \\ V &= 11 \\ \therefore \boxed{11 \text{ mL}} \end{aligned}$$

b) [1 mark] Is the indicator a good one for use in this titration? How do you know?

equivalence point when mmol base = mmol acid
so $1.1 \times 10^{-3} V = 1 \times 10^{-2}$

$$\Rightarrow V = 9.09 \text{ mL}$$

Indicator changes colour 1.91 mL too late

error: $\boxed{21\%}$ $\boxed{\text{No good!}}$

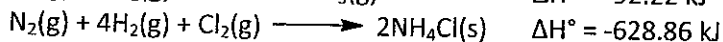
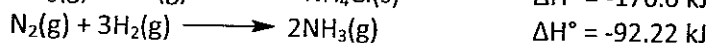
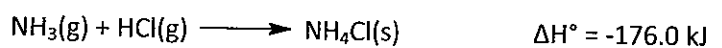
- 8) [2 marks] A balloon is expanded from 2.00 L to 4.00 L at a constant external pressure of 1.50 atm. In the process, it absorbs 2.0 kJ of heat from the surroundings. Calculate q , w , ΔE , and ΔH for the process.

$$q = 2000 \text{ J} = \Delta H$$

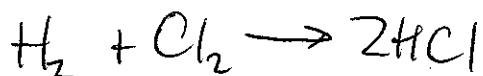
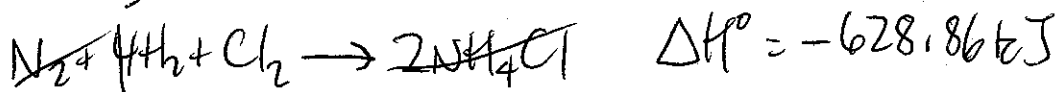
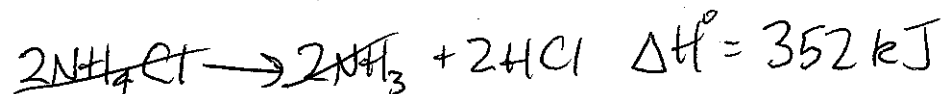
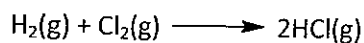
$$w = -1.50 \text{ atm} \times (4-2) \text{ L} \times \frac{101.3 \text{ J}}{1 \text{ L} \cdot \text{atm}} = -304 \text{ J}$$

$$\Delta E = q + w = 1696 \text{ J}$$

- 9) [2 marks] Given the following:

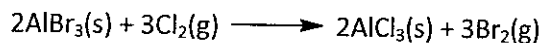


Calculate ΔH° for the reaction



$$\Delta H^\circ = -184.64 \text{ kJ}$$

- 10) [2 marks] Given that the enthalpy of formation for $\text{AlCl}_3(\text{s})$ is -674.8 kJ/mol , and that ΔH° for the reaction



is -327.04 kJ , what is the molar enthalpy of formation of $\text{AlBr}_3(\text{s})$?

$$\begin{aligned} -327.04 &= 2(-674.8) + 3(0) - 2X + 3(0) \\ &= -1349.6 - 2X \\ \Rightarrow X &= \boxed{-511.28 \frac{\text{kJ}}{\text{mol}}} \end{aligned}$$

- 11) [3 marks] The molar heat capacity of liquid "Compound X" is $50.0 \frac{\text{J}}{\text{mol}\cdot\text{K}}$, and of gaseous "Compound X" is $25 \frac{\text{J}}{\text{mol}\cdot\text{K}}$. The boiling point of "Compound X" is 75.0°C . If it took 65 kJ of heat to warm 2.0 moles of "Compound X" from a liquid at 50.0°C to a gas at 90.0°C , what is the molar enthalpy of vaporization of "Compound X"?

$$q_{\text{L}\rightarrow\text{L}} = 2 \text{ moles} \times \frac{50 \text{ J}}{\text{mol}\cdot\text{K}} \times (75 - 50) \text{ K} = 2500 \text{ J}$$

$$+ q_{\text{L}\rightarrow\text{G}} = X \text{ J}$$

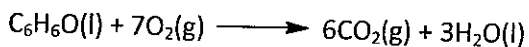
$$+ q_{\text{G}\rightarrow\text{G}} = 2 \text{ moles} \times \frac{25 \text{ J}}{\text{mol}\cdot\text{K}} \times (90 - 75) \text{ K} = 750 \text{ J}$$

$$65000 \text{ J}$$

$$X + 3250 = 65000 \Rightarrow X = 61750 \text{ J}$$

$$\therefore \Delta H_{\text{vap}}^\circ = \frac{61750 \text{ J}}{2 \text{ moles}} = \boxed{30,875 \frac{\text{J}}{\text{mol}} \text{ or } \sim 30.9 \frac{\text{kJ}}{\text{mol}}}$$

12) [4 marks] A 0.9412-g sample of phenol (94.12 g/mol) was burned in a bomb calorimeter with a heat capacity of 10.00 kJ/°C:



The temperature of the calorimeter increased by 3.056°C. Calculate ΔH° for this reaction at 25°C.

$$q_{\text{cal}} = 10 \frac{\text{kJ}}{^\circ\text{C}} \times 3.056^\circ\text{C} = 30.56 \text{ kJ}$$

$$+ q_{\text{rxn}} = -30.56 \text{ kJ}$$

○

$$n_{\text{phenol}} = 0.9412 \text{ g} \times \frac{1 \text{ mol}}{94.12 \text{ g}} = 0.01 \text{ moles } (= n_{\text{rxn}})$$

$$\Delta E^\circ = \frac{-30.56 \text{ kJ}}{0.01} = -3056 \text{ kJ}$$

$$\Delta H^\circ = -3056 \text{ kJ} + (-1)(8.314472)(298.15) \times \frac{1 \text{ kJ}}{1000 \text{ J}}$$

$$= \boxed{-3058.48 \text{ kJ}} \\ (\sim -3058 \text{ kJ})$$