# Chemistry 1154 R25 Fall 2023 Test 3

Friday, November 24, 2023 Time: 1 hour 50 minutes

Name: _____ Student #: _____

*This test consists of **eleven** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **45** marks (and three bonus marks) available. Good luck!*

1) **[13 marks total]** Calculate the pH (at 25°C) of the following solutions. Trimethylamine ($(CH_3)_3N$) is a weak base with $K_b = 6.3 \times 10^{-5}$.

   a) **[3 marks]** 1.59 M $(CH_3)_3N$

b) **[3 marks]** 10 mL of 3.975 M $(CH_3)_3N$ mixed with 15 mL of 1.67 M $(CH_3)_3NHBr$

c) **[4 marks]** 10 mL of 2.5 M $(CH_3)_3N$ mixed with 15 mL of 1.0 M HBr

d) **[3 marks]** 0.63 M $(CH_3)_3NHBr$

2) **[6 marks]** Calculate the pH (at 25°C) of the following solutions. Benzoic acid ($HC_6H_5CO_2$) is a weak acid with $K_a = 6.3 \times 10^{-5}$.

a) 15 mL of 1.0 M $HC_6H_5CO_2$ mixed with 10 mL of 0.75 M KOH

b) 0.63 M $NaC_6H_5CO_2$

3) **[9 marks total]** Calculate the pH (at 25°C) of the following solutions. Fumeric acid ($H_2C_4H_2O_4$) is a polyprotic acid with $K_{a1}$ = 0.015 and $K_{a2}$ = 2.6 x $10^{-7}$.

a) **[2 marks]** 2.00 M $KHC_4H_2O_4$

b) **[3 marks]** 10 mL of 2.00 M $H_2C_4H_2O_4$ mixed with 20 mL of 1.50 M KOH

c) **[4 marks]** Sketch (not necessarily to scale) the complete titration curve you would expect to see for Fumeric acid when titrated with a strong base. On your sketch, indicate:

i) Any buffer regions and the acid species present there
ii) Any equivalence points and the acid species present there
iii) Where the pH is controlled by excess base
iv) Where the end point of the titration would be observed. Assume you are using an indicator with a $pK_a$ of 4

4) **[5 marks total]** A 10 mL aliquot of 0.012 M $HNO_3$ is titrated with 0.01 M KOH. An indicator with a $pK_a$ = 3.00 is used for the titration.

a) **[4 marks]** At what added volume of KOH will the end point be reached?

b) **[1 mark]** Is the indicator a suitable one for the titration? How do you know? (No marks for guessing. ☺)

5) **[2 marks]** Complete the following table:

| Acid | Conjugate Base |
|---|---|
| $HPO_4^{2-}$ | |
| | $OH^-$ |
| $NH_2^-$ | |
| | $CH_3^-$ |

6) **[4 marks]** When 1.99 g of NaOH (40.0 g/mol) is mixed with 100.0 mL of 0.500 M $H_2SO_4$ (S = 4.184 J/g·°C, D = 1.00 g/mL) at 22.68°C, the temperature of the resulting solution increases to 32.01°C. Calculate ΔH for the reaction:

$2NaOH(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$

Give your answer in kJ.

7) **[3 marks]** Given the following reactions:

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$ $\quad \Delta H° = -2599.1$ kJ
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ $\quad \Delta H° = -571.6$ kJ
$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l)$ $\quad \Delta H° = -3120.8$ kJ

Calculate $\Delta H°$ for the reaction

$C_2H_2(g) + 2H_2(g) \longrightarrow C_2H_6(g)$

8) **[1 mark]** Write the thermochemical equation for the formation of $C_2H_6(g)$, for which $\Delta H°_f = -84$ kJ/mol.

9) **[2 marks]** Given that the enthalpy of formation of $CO_2(g)$ is -393.5 kJ/mol, and of $H_2O(l)$ is -285.8 kJ/mol, and given the reaction

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l) \qquad \Delta H° = -2599.1\ kJ$

calculate $\Delta H°_f$ for $C_2H_2(g)$. Give your answer in kJ/mol

**[BONUS – 3 marks]**

The first ionization of $H_2SO_4$ is complete, and $K_{a2} = 0.011$. Calculate the pH of a 0.01 M solution of $H_2SO_4$.