QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

BENCH 1 (30 MINUTES) STATION CODE: ____

The following equipment, glassware and chemicals are on the bench in front of you

- Burette with unknown diprotic acids (phenolphthalein has already been added to this solution).
- Burette with standard sodium hydroxide solution (concentration is on the bottle).
- Two 125 mL Erlenmeyer flasks

Remember: Do NOT add any solutions to the burette. If the burette is empty, ask the instructor to add additional solution. Failure to do so will result in a zero on this question.

Using these items, answer the questions below. In some cases, two blanks are provided in case you wish to complete two trials.

1. (3 pts) Fill out the following table. Precision: -0.1 pt/each, units: -0.1 pt/each.

Identification code for unknown acid:	
Density of unknown acid solution:	12.5 g/L
Molarity of the sodium hydroxide:	0.1500 mol/L

2. (12 pts) Fill out the table below. Precision: -0.3 pt/each, units: -0.3 pt/each.

Initial acid burette reading:	0.50 mL	
Final acid burette reading:	18.50 mL	
Volume of acid in flask:	18.00×10^{-3} L	
Initial base burette reading:	2.25 mL	
Final base burette reading:	24.80 mL	
Volume of base required to reach endpoint:	22.55×10^{-3} L	

3. (2 pts) Instructor approval of endpoint: _____

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

BENCH 2 (30 MINUTES) STATION CODE: ____

The following equipment, glassware and chemicals are on the bench in front of you

- Two graduated cylinders
- Calorimeter
- Pasco temperature probe
- Bottle of acid in tray
- Bottle of base between each pair of stations.

Remember: Do NOT switch acid solutions between trays. Doing so will result in a zero on this question.

Using these items, answer the questions below. In some instances, two blanks are provided in case you wish to complete two trials.

4. (6 pts) Fill out the following table. Precision: -0.1 pt/each, units: -0.1 pt/each.

Calorimeter number:	
Calorimeter constant:	15.0 J/deg
Chemical formula for base:	NaOH
Concentration of base:	1.15 mol/L
Chemical formula for acid:	H_2SO_4
Concentration of acid:	1.00 mol/L

5. (7 pts) Fill out the table below. Precision: -0.2 pt/each, units: -0.2 pt/each.

Volume of base:	20×10^{-3} L	
Moles of base:	23×10^{-3} mol	1.15 mol/L X 20×10^{-3} L
Temperature of base:	22 deg Celsius	
Volume of acid:	20×10^{-3} L	
Moles of acid:	20×10^{-3} mol	1.00 mol/L X 20×10^{-3} L
Temperature of acid:	21 deg Celsius	
Final temperature after reaction:	29.5 deg Celcius	

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

BENCH 3 (30 MINUTES) STATION CODE: ____

The following glassware are on the bench in front of you

- Item A: 50 mL beaker
- Item B: 600 mL beaker
- Item C: 10 mL graduated cylinder
- Item D: 50 mL graduated cylinder
- Item E: 100 mL graduated cylinder
- Item F: 50 mL volumetric flask
- Item G: 100 mL volumetric flask
- Item H: burette

Remember: Do NOT change the amount of liquid in any of these items. Doing so will result in a zero on this question.

Using these items, answer the questions below.

6. (24 points) Use the list above and identify the glassware based on description. Once identified, place the code from the glassware into the appropriate box. Then, determine the volume of liquid in each of the and input this information in the table below to the correct precision with the correct units. If you cannot determine the volume, indicate this by writing "Cannot determine". (Precision: - 1 point/each; Units: - 1 point/each).

	Code	Volume
Item A:		27 mL
Item B:		310 mL
Item C:		5.45 mL
Item D:		25.5 mL
Item E:		52.5 mL
Item F:		About half full (unreadable)
Item G:		100.00 mL
Item H:		26.55 mL

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

Answer the following questions using the data acquired at Bench 1. (20% for units and precisions)

7. (5 pts) Write the balanced chemical reaction for a general aqueous diprotic acid (H_2X) reacting with aqueous sodium hydroxide. Be sure to indicate the phases for all reactants and products.

$$H_2X_{(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(l)} + Na_2X_{(aq)}$$

8. (10 pts) What is the molar mass of the diprotic acid?

grams of H_2X = 12.5 g/L X 18.00 X 10^{-3} L = 0.225 g

Mol of NaOH = 0.1500 mol/L X 22.55 X 10^{-3} L = 3.383 X 10^{-3} mol

From chemical equation, 1 mol of H_2X reacts with 2 mol of NaOH

$$\text{Mol of } H_2X = (3.383 \times 10^{-3} \text{ mol NaOH} \times (\frac{1 \text{ mol } H_2X}{2 \text{ mol NaOH}}) = 1.691 \times 10^{-3} \text{ mol}$$

Molar mass of H_2X = 0.225 g of H_2X ÷ 1.691 X 10^{-3} mol = 133 g/mol

9. (3 pts) What is the difference between a stock solution and a standard solution?

A stock solution is a concentrated solution that can be stored for a long time.

A standard solution is a dilution of a stock solution. The concentration of a standard solution is set by titrating aliqouts with a known amount of a high purity reagent.

10. (5 pts) Write an experimental procedure for the standardization of the sodium hydroxid solution that was used.

The stock solution is usually 2 or 3 mol/L. Let's assume it is 3 mol/L and you want to prepare 400 mL of a Sodium Hydroxide solution with approximate concentration 0.1 mol/L.

Use the standard formula $C_iV_i = C_fV_f$
C_i, V_i = Initial concentration and volume
C_f, V_f = Final concentration and volume

$$(3\ \text{mol/L})\ V_i = (0.1\ \text{mol/L})\ 400 \times 10^{-3}\ \text{L}$$

$$V_i = \frac{(0.1\ \text{mol/L})\ 400 \times 10^{-3}\ \text{L}}{(3\ \text{mol/L})}$$

$$V_i = 13.3 \times 10^{-3}\ \text{L}$$

$$V_i = 13.3\ \text{mL}$$

Thus you will need 13.3 mL of 3 mol/L stock solution then add DI water to make 400 mL of solution: (400 - 13.3) = 386.7 mL.

However, the volume does not need to be exact because you need to standardize the solution. How do we calculate the exact concentration of dilute sodium hydroxide from the titration data?

Say you prepared a standard KHP solution by dissolving 4.5 g of KHP in 250 mL of water. Note the KHP does not have to be exactly 4 or 5 g, but the amount must be known exactly.
Now suppose you take 35.00 mL out of the 250 mL KHP solution and titrate with the dilute Sodium Hydroxide solution. The equivalence point is reached after you add 32.50 mL of the dilute Sodium Hydroxide solution into the 35.00 mL of KHP solution.

$$\text{Mol of KHP in 4.5 g} = \frac{4.5\ \text{g}}{204.22\ \text{g/mol})} = 0.022035\ \text{mol}$$

$$\text{KHP in 35.00 mL} = \frac{35}{250} \times 0.022035\ \text{mol} = 0.0030849\ \text{mol}$$

Recall that mol of KHP = mol of NaOH

$$KHP + NAOH \rightarrow KNaP + H_2O$$

$$\text{Molarity of NaOH} = \frac{0.0034049\ \text{mol}}{32.50 \times 10^{-3}\ \text{L}} = 0.09492\ \text{mol/L}$$

Thus your standard Sodium Hydroxide solution has a concentration of **0.09492 mol/L**, which is very close to the 0.1 mol/L we were aiming to when making the dilution from the 3 mol/L stock solution.

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

Answer the following questions using the data acquired at Bench 2. (20% for precision and units)

11. (5 pts) Write the balanced chemical reaction for the reaction of the aqueous base and the acid. Be sure to indicate the phases for all reactants and products.

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$$

12. (7 pts) Which reactant is limiting for your system? Show all work.

mol of base = 1.15 mol/L X 20 X 10^{-3} L = 23 X 10^{-3} mol

mol of acid = 1.00 mol/L X 20 X 10^{-3} L = 20 X 10^{-3} mol

From the chemical equation the acid to base mol ratio is 1:2

To react 23 X 10^{-3} mol of Base we need 11.5 X 10^{-3} mol of Acid

To react 20 X 10^{-3} mol of Acid we need 40 X 10^{-3} mol of Base

Then the Base is limiting

13. (5 pts) For this experiment, assume that the density of both the acid solution and the base solution is 1.045 g/mL. What is the total mass of solution for your trial?

mass of Base = 20 mL X 1.045 g/mL = 20.9 g

mass of Acid = 20 mL X 1.045 g/mL = 20.9 g

Total mass = 20.9 g + 20.9 g = 41.8 g

14. (5 pts) What is the heat of reaction? Use the average temperature of the acid and base as the initial temperature. Show all work.

Acid Temp = 21 deg, Base Temp = 22 deg, Aver. Temp = 21.5 deg Celsius

Delta T = 29.5 deg - 21.5 deg = 8.00 deg

Q = [mc(Delta T)water] + [C (Delta T)calorimeter]

Q = [41.8 g X (4.18 J/g x deg) x 8.00 deg] + [15 J/deg x 8.00 deg]

Q = 1398 J + 120 J = 1518 J = 1.52 kJ

15. (5 pts) What is the molar reaction enthalpy for the reaction?

H = -Q
H = -1.52 kJ

This is the standard enthalpy in terms of acid

Delta H = H ÷ Number of mol

Delta H = -1.52 kJ ÷ 11.5 X 10-3 mol H_2SO_4

Delta H = 132 kJ/mol of H_2SO_4

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

Answer the following questions using the data acquired at Bench 3. (50% for precision and units)

16. (8 pts) The solution in Item G was prepared by dissolving 1.43 grams of ferrous sulfate heptahydrate in water and then filling to the line. What is the molarity of the solution? (H, 1.008 g/mol; O, 15.999 g/mol; Fe, 55.845 g/mol; S, 32.065 g/mol)

Ferrous Sulfate Heptahydrate = $FeSO_4 \cdot 7H_2O$

55.845 + 32.065 + (4 X 15.999) + (7 X 18.015) = 278.050 g/mol

mol of Compound = 1.43 g ÷ 278.050 = 0.514 mol

Molarity = 0.514 ÷ 100.00 X 10^{-3} L = 5.14 mol/L

17. (8 pts) Item H contains 0.2563 M sodium hydroxide. This item was used to titrate 30.00 mL of a solution of potassium hydrogen phthalate. The initial volume reading of the item was 1.34 mL. What is the concentration of the KHP?

Volume of NaOH used = 25.5 mL - 1.34 mL = 24.16 mL

mol of NaOH = 0.2563 M X 24.16 X 10^{-3} L = 6.192 X 10^{-3} mol

Reaction of NaOH with KHP is 1:1

NaOH + KHP --> KNaP + H_2O

mol of KHP = mol of NaOH

Concentration of KHP = 6.192X 10^{-3} mol ÷ 30.00X 10^{-3} L = 0.206 M

18. Item D contains a 0.210 M solution of barium nitrate. Item E contains a 0.110 M solution of sodium sulfate. Answer the following questions. (Note: Ba, 137.327 g/mol; N, 14.007 g/mol; O, 15.999 g/mol; S, 32.065 g/mol)

a. (5 pts) What is the name and chemical formula of the precipitate formed?

The precipitate is Barium Sulfate = $BaSO_4$

b. (10 pts) What is the mass of the precipitate formed when these two items are mixed? Assume that the reaction goes to completion.

25.5×10^{-3} L X 0.210 mol/L = 5.355×10^{-3} mol $Ba(NO_3)_2$

52.5×10^{-3} L X 0.110 mol/L = 5.775×10^{-3} mol Na_2SO_4

Barium Nitrate is limiting, there are 5.355×10^{-3} mol $BaSO_4$ formed

BaSO4 = 137.327 + 32.065 + (4 X 15.999) = 233.388 g/mol

mass of precipitate = 5.355 mol X 233.388 g/mol = 1.250 grams

c. (20 pts) What is the concentration of each of the ions remaining in solution?

5.355×10^{-3} mol $Ba(NO_3)_2$
5.775×10^{-3} mol Na_2SO_4

This is what we have in a volume of

25.5 mL + 52.5 mL = 78.0×10^{-3} L

The Barium is all used so its concentration is Zero

Some Sulfate ions remain: the ones that are not part of the precipitate
mol of Sulfate ion = $(5.775 - 5.355) \times 10^{-3}$ mol = 0.42×10^{-3} mol
Sulfate ion concentration = 0.42×10^{-3} mol ÷ 78.0×10^{-3} L = 5.38×10^{-3} M

There are two Nitrate ions per Barium Nitrate unit
mol of Nitrate ion = $2 \times 5.355 \times 10^{-3} = 10.71 \times 10^{-3}$ mol
Nitrate ion concentration = 10.71×10^{-3} mol ÷ 78.0×10^{-3} L = 0.1373 M

There are two Sodium ions per Sodium Sulfate unit
mol of Sodium ion = $2 \times 5.775 \times 10^{-3} = 11.55 \times 10^{-3}$ mol
Sodium ion concentration = 11.55×10^{-3} mol ÷ 78.0×10^{-3} L = 0.1481 M

QUEENS COLLEGE

Chemistry 113.1
Introduction to Chemical Techniques
Final Examination

Name: **Date:**

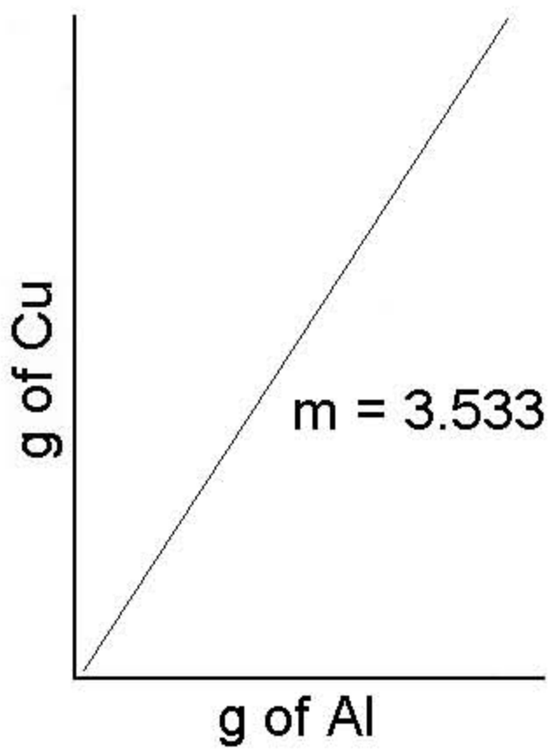
Answer the following questions using the information available in your laboratory notebook.

19. (10 pts) Various amounts of solid aluminium was reacted with aqueous copper(II) solution. The mass of solid copper produced from this experiment was plotted versus the mass of aluminium reacted. What should the slope of the line that goes through the data points be equal to? (Note: Cu, 63.546 g/mol; Al, 26.982 g/mol)

The stoichiometry of the reaction is 3 mol of Copper for 2 mol Aluminium

$3Cu^{2+} + 2Al^{0} \rightarrow 3Cu^{0} + 2Al^{3+}$

$$\frac{3 \text{ X } 63.546 \text{ Cu}}{2 \text{ X } 26.982 \text{ Al}} = \frac{190.638 \text{ Cu}}{53.964 \text{ Al}} = 3.533 \frac{\text{Cu}}{\text{Al}}$$



20. A sample of 4.250 g of sodium carbonate decahydrate is dried in a crucible using direct heat. After heating until the sample reached constant mass, the sample weighed less than it did initially. Answer the following questions.

a. (5 pts) Why did the mass change?

The mass changed because the water in the hydrate evaporated when the sample was heated.

b. (5 pts) What was the final mass of the sample?

Add up the molar masses of the elements in the formula

$Na_2CO_3 \cdot 10H_2O = 286.14$ g/mol

Fraction of water = (10 X 18.015 g/mol) ÷ 286.14 g/mol = 0.62959

mass of water = 4.250 g X 0.62959 = 2.676 g

Final mass = 4.250 g - 2.676 g = 1.574 g