What Is the Identity of That Dicarboxylic Acid?

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Group member: Kobe **Group member:** Jerry

20 minutes to next solid line

Information: For this laboratory, previously used techniques will be used to determine the identity of an unknown substance. A sample of sand is contaminated with an unknown dicarboxylic acid. A dicarboxylic acid has two protons for an acid-base reaction. To reflect this, we will represent a dicarboxylic as H_2A. The H_2 in the formula represents two protons (2 H^+ ions) available for the acid-base reaction. You have been tasked with identifying the H_2A in the sand. You quickly reason that determining the molar mass will be your primary objective. Once the molar mass is obtained, you can search reliable sources to discover its identity.

Model 1: Determining the molar masses of unknown substances.

Key Questions:

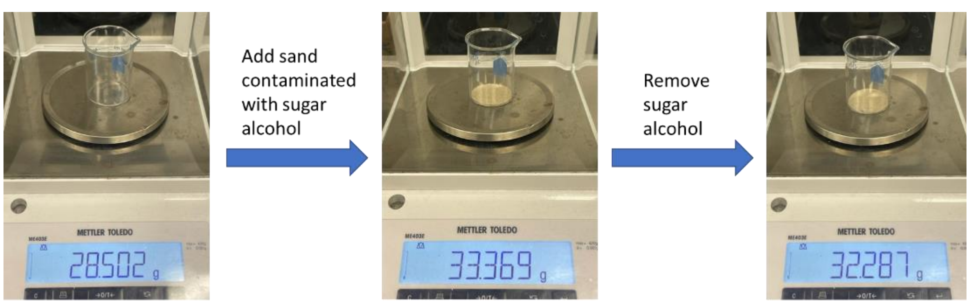
1. What are the two units for molar mass? If each of these units was determined for a pure substance (such as H_2A or some other compound), you can calculate the molar mass.

   mass (grams) and moles

2. Let's suppose that you have a sample of sand contaminated with a sugar alcohol.
   a. How can you separate the sugar alcohol from the sand? You used this technique in the Physical Properties lab.

      Evaporate the sugar alcohol so it leaves the sand behind

   b. You perform the technique described above. What was the mass of the sugar alcohol in the contaminated sand? Show your work.



beaker — Beaker, sand, and sugar alcohol — Beaker and sand

      33.369 - 32.287 = 1.082 g

   c. Your teacher tells you that the amount of sugar alcohol in the contaminated sand is 0.003145 moles. Determine the molar mass.

$$\frac{1.082g}{0.003145mol} = 344.0\,\frac{g}{mol}$$

d. You search Google and find the following molar masses for several sugar alcohols: sorbital – 182 g/mol; erythritol – 122 g/mol; and maltitol – 344 g/mol. What is the likely identity of the sugar alcohol?

Maltitol

3. Similarly, determining the mass of an unknown dicarboxylic acid in sand probably won't be too difficult provided that it is soluble as well. You would still be lacking moles to determine the molar mass.

   a. Previously, you utilized a technique from which you determined the amount of an acid using a base of known concentration. What was this technique?

   titration

   b. The balanced chemical equation for the neutralization of a dicarboxylic acid with sodium hydroxide is shown below. Why is the mole ratio 1:2 for the acid and the base?

   $H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$

   The coefficient for the dicarboxylic acid is 1 and for the sodium hydroxide it's 2.

   c. Let's assume that you have available 0.0852 *M* NaOH. You perform the reaction above and determine that 8.23 mL of the NaOH reacts completely with the unknown dicarboxylic acid. How many moles of H_2A are in the contaminated sand? Show your calculation.

$$0.00823L \cdot \frac{0.0852mol}{L} = 0.0007012mol \qquad 0.000702mol, NaOH \cdot \frac{1mol.H_2A}{2mol, NaOH} = 0.000351mol, H_2A$$

<u>Exercises:</u>

4. A 50.0 mL solution contains 0.626 grams of a *tri*carboxylic acid (H_3A). You remove 5.00 mL of this solution and transfer it to a flask. You perform a titration and discover that 5.93 mL of a 0.195 M NaOH solution reacts completely with the contents in the flask.

   a. Write the balanced chemical equation for the neutralization reaction between the tricarboxylic acid, H_3A, and the NaOH.

   $$H_3A\,(aq) + 3NaOH\,(aq) \rightarrow Na_3A\,(aq) + 3H_2O\,(l)$$

   b. How many moles of H_3A were transferred to the flask. Show your calculation.

$$0.00593L \cdot \frac{0.195mol}{L} = 0.001156mol, NaOH \qquad 0.001156mol, NaOH \cdot \frac{1molH_3A}{3mol, NaOH} = 0.0003853mol, H_3$$

c. The calculation performed above is only for a small volume (5.00 mL) removed from the original tricarboxylic acid solution. How many moles of H_3A were in the original solution of 50.0 mL? Show your work.

$$\frac{0.0003853mol}{5mL} \cdot 50mL = 0.003853mol$$

d. Now, determine the molar mass of your tricarboxylic acid.

$$\frac{0.626g}{0.003853mol} = 162.5\,\frac{g}{mol}$$

Entire class discussion:

Method development:

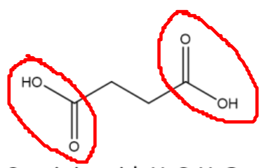
Items needed for each member of the group: Vial of sand-dicarboxylic acid mixture (first bench, vials for each group member need to come from a different container), 50 mL beaker, scoopula, small funnel, 50 mL graduated cylinder, and 50 mL volumetric flask.

5. Each group member needs to select one of the vials of sand-dicarboxylic acid mixture from a different container (labeled 1-4). *No two group members should select a vial from the same container*. Each vial has a number. Fill in the below information for each group member.

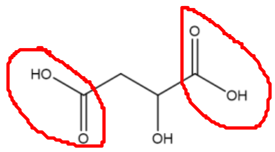
Group member name	**Number on container or first number on vial (1-4)**	**Second number on vial**
Jerry	1	14
Brodric	2	116
Kobe	3	97
Chris	4	208

6. The unknown dicarboxylic acid for each group member is one of the following. Each one is soluble in water. How do you know they are soluble by looking at the structures?

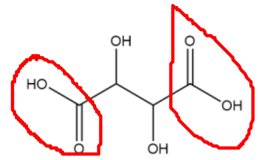
They all have H-bonds like how water does, and like dissolves like.



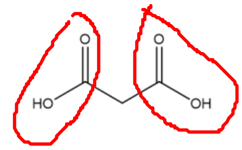
Succinic acid, $H_2C_4H_4O_4$



Malic acid, $H_2C_4H_4O_5$



Tartaric acid, $H_2C_4H_4O_6$



Malonic acid, $H_2C_3H_2O_4$

7. A carboxylic acid is a compound in which a carbon atom is bonded to an oxygen atom by a double bond *and* to a hydroxyl group (OH) by a single bond. Each of the compounds above contain *two* carboxylic acid groups. Circle them in each compound.
8. The solid dicarboxylic acid needs to be removed (or extracted) from the mixture. Describe a method to perform this separation. <u>Note: You will need to keep the extracted liquid since it will contain the dicarboxylic acid.</u>

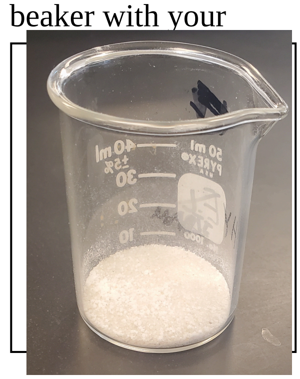
Mix with distilled water so it gets the acid off the solid and then dry it dso you're left with just the solid

<u>Individual data collection (each person in the group will acquire their own data):</u>

9. Describe the contents in the vial you are analyzing.

   White grainy crystals, some darker brownish and some white

10. The below information will assist you in performing the extraction of the dicarboxylic acid from the mixture.
    a. Clean and dry a 50 mL beaker (if needed). Label the 50 mL beaker with your initials and acquire the mass of the empty beaker.

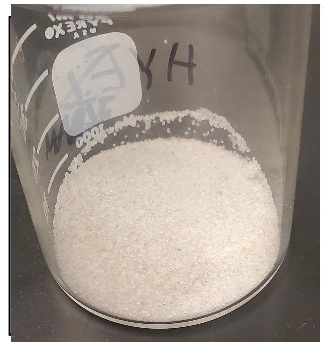


    b. Pour *all* the contents from the vial into the beaker. Tap the vial and use a scoopula to transfer all the mixture. Acquire the mass of the beaker *with* the sand-dicarboxylic mixture. With your cell phone take a picture of the solid.
    c. Acquire a 50 mL volumetric flask (clean, if necessary, with distilled water). Note: It doesn't need to be dry. Label the flask with your initials.
    d. Separate the dicarboxylic acid from the sand by performing *three* extractions. For each extraction add 12-14 mL of distilled water to the beaker with the sand-dicarboxylic mixture. Stir the mixture gently with the spatula for 1 minute. Allow 1 minute for the solid to settle. Remove the liquid from the remaining solid by carefully pouring it into a 50 mL volumetric flask (see picture). You want to maximize the amount of liquid removed while keeping the solid in the beaker. Do this procedure (called

extraction) three times. Note: You must collect the liquid in the volumetric flask since it contains the dicarboxylic acid. It will be analyzed later.

e. After the three extractions, place your labeled beaker with the solid on the provided aluminum tray. Your teacher will put it in the oven for 15 minutes at 375°F (191°C). While waiting, you are encouraged to start the next section.

f. After the beaker is cool, acquire a mass of the beaker and solid. With your cell phone take a picture of the remaining solid.



Mass of 50 mL beaker	Mass of beaker and sand-acid mixture (before separation)	Mass of beaker and sand (after separation)
30.087 g	36.802 g	36.305

g. Fill in the following table.

Mass of sand-acid mixture only (before separation)	Mass of sand (after separation)	Mass of dicarboxylic acid
6.715 g	6.218 g	0.467 g

<u>Compilation of group data and group analysis:</u>

11. What is primarily in the 50 mL beaker *after* the extractions have been performed?

Sand

12. Describe the appearance of the solution in the volumetric flask?

clear, appears like water

13. You have determined the mass of the dicarboxylic acid in the sand-dicarboxylic acid mixture. What else is needed to determine the molar mass of the dicarboxylic acid?

Moles of the acid

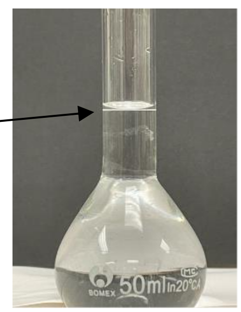
Method development:

Items needed for each member of the group: Burette attached to stand, container of sodium hydroxide solution (1 container per group), adjustable pipette (located on the first bench), pipette tip (located on first bench), 150 mL beaker, 50 mL Erlenmeyer flask, and phenolphthalein indicator (1 container per group).

14. Examine the burette. In which place is the estimated digit? hundredths
15. You are going to perform a titration on the unknown dicarboxylic acid in the volumetric flask by using a provided sodium hydroxide solution of known concentration. A large container of this sodium hydroxide solution is in the hood which is used to fill the small container. What is the concentration (indicated on large container)? 0.2494 M
16. Describe a method to perform this titration. The information in Model 1 will also assist you in describing this method.

    add the identifyer stuff to do a titration on the acid and find out how many mL it takes of NaOH when it's complete, then using it's molarity and the mole ratios in the formula

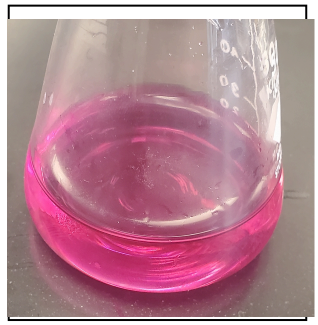
Individual data collection (each person in the group will acquire their own data):



17. The volume of dicarboxylic acid solution in your volumetric flask should be below the 50.0 mL mark. Carefully fill the volumetric flask with distilled water until the bottom of the meniscus is level with this mark. Stopper the flask, and while holding the stopper, invert the flask several times to thoroughly mix the contents.
18. Open the valve on the 10 mL burette, allow it to empty, and rinse with several small portions of the NaOH solution. Allow the rinse to drain completely through the stopcock into a waste beaker (the 150 mL beaker). Close the valve on the burette until the liquid just barely stops flowing through the tip. Note: DO NOT OVERTIGHTEN THE VALVE WHEN CLOSING! Fill the burette with the NaOH solution. Open the stopcock and allow the burette tip to fill with solution. Record the initial burette reading in the table below. Note: The reading needs to be between 0.00 mL and 0.50 mL. Add more NaOH solution if it is not.
19. Transfer 10.0 mL of your dicarboxylic acid solution into the Erlenmeyer flask using the adjustable pipette. Make sure to label the pipette tip with your initials.
20. Add 1-2 drops of the phenolphthalein indicator to the dicarboxylic acid solution. What is the color of the indicator in the solution (record this in the table below)?
21. You will now add the NaOH solution from the burette to the dicarboxylic acid solution in the flask until the acid-base reaction is complete (the endpoint is acquired). Remember,

the endpoint is acquired when the solution just barely turns pink (and stays pink when mixed).

a. You can safely add 4.0 mL of NaOH solution from the burette without reaching the endpoint. Make sure to swirl the solution after each addition.
b. After adding 4.0 mL of NaOH solution from the burette, you will carefully add a the NaOH solution dropwise (drop by drop) and swirl the contents in the flask after each addition.
c. Keep adding the NaOH solution dropwise and swirling until the endpoint is acquired. The solution should barely turn pink and stay that color. Record the final volume on the burette. This should not take more than 9.0 mL.
d. What is the color of the solution at the endpoint (record in the table below)? Take a clear picture of this solution *at the endpoint*.

e. Determine the volume of NaOH solution added to the flask and place it in the table.
f. Discard the contents of the flask in the sink, rinse the flask with distilled water, fill with another 10.0 mL of dicarboxylic acid solution, refill the burette with dilute NaOH solution, and perform another titration (Trail 2).

<u>Note:</u> the volume of NaOH solution added should be very close for Trials 1 and 2 (within 0.30 mL). If they are not, perform another trial.

	Trial 1	**Trail 2**
Initial burette reading for NaOH solution	0.00 mL	0.00 mL
Volume of dicarboxylic acid solution	10.0 mL	10.0 mL
Color of indicator in dicarboxylic acid solution *before* endpoint	colorless	colorless
Final burette reading for NaOH solution	6.05 mL	6.15 mL
Color of indicator in dicarboxylic acid solution *at* endpoint	pink	pink
Volume of NaOH solution added to flask	6.05 mL	6.15 mL

Moles of NaOH added to reaction	0.001509 mol	0.001533 mol
Moles of dicarboxylic acid neutralized	0.0007545 mol	0.0007665 mol
Moles of dicarboxylic acid in 50.0 volumetric flask	0.003773 mol	0.003833 mol
Molar mass of dicarboxylic acid	123.8 g/mol	121.8 g/mol
Average molar mass of dicarboxylic acid		122.8 g/mol

22. Using the molarity of the NaOH solution, determine the moles of NaOH that was added from the burette for this reaction. Do this for each trial. Show your work and use dimensional analysis. Place these values in the table.

Trial 1:

$$0.00605L \cdot 0.2494\,\frac{mol}{L} = 0.001509mol$$

Trial 2:

$$0.00615L \cdot 0.2494\,\frac{mol}{L} = 0.001533mol$$

23. From the balanced chemical equation for a dicarboxylic acid, calculate the moles of the dicarboxylic acid that was neutralized by the NaOH. Do this for each trial. Show your work and use dimensional analysis. Place these values in the table.

Trial 1:

$$0.001509mol, NaOH \cdot \frac{1mol, acid}{2mol, NaOH} = 0.0007545mol, acid$$

Trial 2:

$$0.001533mol, NaOH \cdot \frac{1mol, acid}{2mol, NaOH} = 0.0007665mol, a$$

24. The moles of carboxylic acid calculated above were for only 10.0 mL. Determine the *total* number of moles of dicarboxylic acid that were in the 50.0 mL volumetric flask. Do this for each trial. Show your work. Place these values in the table.

Trial 1:

$$\frac{0.0007545mol}{10mL} \cdot 50mL = 0.003773mol$$

Trial 2:

$$\frac{0.0007665mol}{10mL} \cdot 50mL = 0.003833mol$$

25. You now have the needed information to determine the molar mass for your unknown dicarboxylic acid. Perform these calculations and place these in the table above. You need to also determine an average molar mass.

Trial 1:

$$\frac{0.467g}{0.003773mol} = 123.8\,\frac{g}{mol}$$

Trial 2:

$$\frac{0.467g}{0.003833} = 121.8\,\frac{g}{mol}$$

26. Fill in the table below for your dicarboxylic acid.

Number on container or first number on the vial (1-4)	Second number on the vial	Average molar mass
2	116	122.8

Compilation of group data and group analysis:

27. Fill in the following table for each group member. Based on the experimentally determined molar mass, input the identity of the dicarboxylic acid. The identity of the dicarboxylic acid will be one of the four dicarboxylic acids given above.

	First number (1-4)	Second number	Molar mass	Identity
Group member	1	14	120.7	succinic acid
Group member	2	116	122.8	succinic acid
Group member	3	97	150.4	tartaric acid
Group member	4	208	99.67	malonic acid

Ask the teacher or lab assistant to check your values above before proceeding.

Class data: In the class data sheet (link in Canvas), input the number of the container from which each group member's vial was taken and its molar mass.

Make sure all items are clean and return them to the drawer or bench. Finish cleaning any glassware used by rinsing with distilled water. Before you leave, ask the teacher or lab assistant to examine your data and laboratory space. Note: Your data must be entered into the spreadsheet before you leave.

Application of Principles (to be completed individually):

28. A friend of yours performed the laboratory above to determine the identity of an unknown carboxylic acid. This friend, however, was not very careful, and a significant amount of sand was poured out of the beaker. Would the determined molar mass be more, less, or unaffected by this error? Explain.

It would be greater because the acid would appear to have a greater mass and a bigger number in the numerator will will a bigger result

29. A mixture contains sand and a tricarboxylic acid (H_3A). The total mass of the mixture was 5.586 grams. Three extractions were performed, and the remaining sand was dried and weighed, having a final mass of 4.882 grams. The final volume from the extractions was 100.0 mL. Using a pipette, 15.0 mL from this volume was transferred to an

Erlenmeyer flask. A burette was filled with a 0.152 M NaOH solution with an initial reading of 0.33 mL. The contents in the Erlenmeyer flask were reacted until the endpoint with the NaOH solution in the burette (final reading of 8.92 mL). You must show your work by writing below or inserting a picture of your work

a. Determine the molar mass of the tricarboxylic acid.

Mass of acid = $5.586g - 4.882g = 0.704g$

Moles of NaOH reacted = $(0.00892L - 0.00033L) \cdot \frac{0.152mol}{L} = 0.001306mol$

Moles of acid reacted = $0.001306mol, NaOH \cdot \frac{1mol, acid}{3mol, NaOH} = 0.0004353mol, acid$

Total moles of acid = $\frac{0.0004353mol}{15mL} \cdot 100mL = 0.002902mol, acid$

Molar mass of acid = $\frac{0.704g}{0.002902mol} = 242.6 \frac{g}{mol}$

b. You were told that the tricarboxylic acid is most likely citric acid, $H_3C_6H_5O_7$. Does your data support this? Explain.

No it doesn't. The molar mass of citric acid is 192.124 g/mol while the molar mass I got for the given acid is 242.6 which is pretty far off

30. You are now going to compare your individual molar mass value with the class average value in the *Class Data Sheet*. Make sure the *Class Data Sheet* is complete before doing this. You will have to wait until the end of the lab period. Fill in the following table below.

	Your individual value	**Average value of class**
Molar mass of H_2A	122.8 g/mol	133.9 g/mol

The agreement between a measured value and an accepted value can be analyzed by performing a percent error calculation (equation given below). For this calculation, the measured value is your individual value, and the accepted value is the class average (in Google Sheet).

$$Percent\ Error = \frac{(measured\ value - accepted\ value)}{accepted\ value} \times 100.0\%$$

a. Calculate a percent error for your individual value. Show your work!

	Percent error
Molar mass of H_2A	-8.290%

$$\frac{122.8 - 133.9}{133.9} \cdot 100\% = -8.290\%$$

b. If your percent error is greater than 10% (or less than -10%), suggest at least one reason for your individual value being significantly different than the accepted value.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.630	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.95	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (265)	105 **Db** (268)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

* Lanthanide series	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
# Actinide series	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)