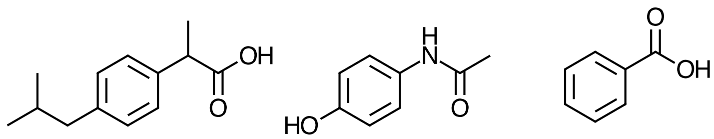
Exam 1 solutions

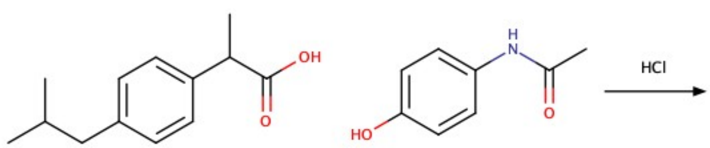
1. Is it safe to mix medicines together or take different medicines at the same time?
Ibuprofen ($C_{13}H_{18}O_2$, 206 g/mole) and Acetaminophen ($C_8H_9NO_2$, 151 g/mole) are common over-the-counter (OTC) pain relievers. Benzoic acid ($C_7H_6O_2$, 122 g/mole) was used as a pain reliever in the early 20th century.



Ibuprofen Acetaminophen Benzoic Acid

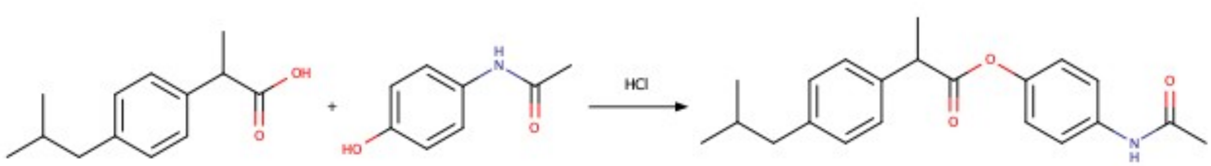
a. At 25°C, the solubility of ibuprofen, acetaminophen, and benzoic acid in water is 21 mg/liter, 13 g/liter, and 3.4 g/liter, respectively.
The chemical force(s) that exist between water and ibuprofen is/are ___. Acetaminophen is the most soluble in water and ibuprofen is the least soluble in water because ___.
Blank 1: check the boxes that apply. Blank 2: give reasons in “Other”.
covalent bonds (blank 1)
ionic bonds (blank 1)
London dispersion forces (blank 1)
dipole-dipole forces (blank 1)
hydrogen bonds (blank 1)
Other
More hydrogen bonds can form between water and acetaminophen (2 O and 1N in the two polar alcohol and amide functional groups) than between water and ibuprofen (2 O in one polar acid functional group).

b. You have a headache and decide to take one tablet of ibuprofen and one tablet of acetaminophen. A reaction occurs in your stomach with the acid (HCl) in your stomach acting like a catalyst.
The ___ functional group in ibuprofen reacts with the ____ group in acetaminophen. The chemical formula of the product of this reaction between ibuprofen and acetaminophen is ___. It is a __ idea to take ibuprofen and acetaminophen at the same time.
Blank 1: give a one word answer. Blank 2: give a one word answer. Blank 3: Write the formula as CxHyOzNw. Make sure each subscript is a number. Blank 4: give a one word answer. Separate each answer with a number.



ibuprofen acetaminophen

Acid, alcohol, $C_{21}H_{25}O_3N_1$, bad.
Note: the acid functional group is short for carboxylic acid (not carboxyl). The hydroxyl group is an O-H group that is contained in an alcohol group and acid group. Hydroxyl group should not be used to identify an alcohol group.



ibuprofen acetaminophen

c. You drink one cup (240 ml) of water when you take one tablet of ibuprofen and one tablet of acetaminophen. The water makes the reaction between ibuprofen and acetaminophen go ___ because ___.

Blank 2: give reasons in “Other”
faster (blank 1)
slower (blank 1)
same rate (blank 1)
Other
Water lowers the concentration of reactants and reduces the number of collisions and reaction rate (rate is proportional to concentration).

d. The ibuprofen and acetaminophen reaction is slow. HCl is used as a catalyst in this reaction. The rate law for the ibuprofen and acetaminophen reaction with the HCl catalyst is: rate = k [ibuprofen] [HCl]. This rate law tells me __ molecules of ibuprofen reacts with 1 molecule of ___ and makes the ___ more reactive to make the reaction go ___.
0 (blank 1)
1 (blank 1)
2 (blank 1)
ibuprofen (blank 2)
acetaminophen (blank 2)
HCl (blank 2)
ibuprofen (blank 3)
acetaminophen (blank 3)
HCl (blank 3)
faster (blank 4)
slower (blank 4)
same rate (blank 4)

e. Table 1 shows 3 experiments for the reaction of ibuprofen and acetaminophen at body temperature.

Table 1. Effect on concentration on rate.

Experiment	[ibuprofen], M	[acetaminophen], M	[HCl], M	Rate, M/min
1	0.3	0.5	6	1.5
2	0.9	0.5	6	Blank 1
3	0.3	1.5	6	Blank 2

Blank 1: Calculate the rate of Experiment 2. Give a number only. Do not include text.
4.5
rate = k [ibuprofen] [HCl]. [ibuprofen] triples and [HCl] is constant in Exp 2 compared to Exp 1 so rate triples.
(Rate of Exp 2/Rate of Exp 1) = (k [0.9] [6])/(k [0.3] [6]) = 3
Blank 2: Calculate the rate of Experiment 3. Give a number only. Do not include text.
1.5
rate = k [ibuprofen] [HCl]. [ibuprofen] is constant, [HCl] is constant, and [acetaminophen] triples but is 0^{th} order in Exp 3 compared to Exp 1 so rate does not change.
(Rate of Exp 3/Rate of Exp 1) = (k [0.3] [6])/(k [0.3] [6]) = 1

Experiment 1 is ___ than Experiment 3 because ____.
Blank 2: give reasons in “Other”
faster (blank 1)
slower (blank 1)
same rate (blank 1)
Other
Rate law shows rate depends on ibuprofen and HCl. Acetaminophen is NOT part of the rate law so [Acetaminophen] does not affect the rate so Experiment 3 is the same rate as Experiment 1.

f. Ibuprofen is $C_{13}H_{18}O_2$ and Acetaminophen is $C_8H_9NO_2$. Consider the two reaction mechanisms:

Mechanism (i): $C_{13}H_{18}O_2 + C_8H_9NO_2 \rightarrow C_{21}H_{27}NO_4$ Step A
$C_{21}H_{27}NO_4 \rightarrow C_{21}H_{25}NO_3 + H_2O$ Step B

Mechanism (ii): $C_{13}H_{18}O_2 + HCl \rightarrow C_{13}H_{19}O_2^{+} + Cl^{-}$ Step 1
$C_{13}H_{19}O_2^{+} + C_8H_9NO_2 \rightarrow C_{21}H_{28}NO_4^{+}$ Step 2
$C_{21}H_{28}NO_4^{+} \rightarrow C_{21}H_{25}NO_3 + H_2O + H^{+}$ Step 3
$H^{+} + Cl^{-} \rightarrow HCl$ Step 4

A catalyst ___. Mechanism __ represents the reaction of ibuprofen and acetaminophen in my stomach. The ___ tells me the rate determining step is ___. Mechanism (i) has a ___ activation energy than Mechanism (ii). *(Forgot to include energy so everyone got credit for Blank 4.)*
increases reaction rate and is not involved in the reaction mechanism and is regenerated at the end of the reaction and is not involved in the overall reaction (blank 1)
increases reaction rate and is involved in the reaction mechanism and is not regenerated at the end of the reaction and is not involved in the overall reaction (blank 1)
increases reaction rate and is involved in the reaction mechanism and is regenerated at the end of the reaction and is not involved in the overall reaction (blank 1)
increases reaction rate and is not involved in the reaction mechanism and is regenerated at the end of the reaction and is involved in the overall reaction (blank 1)
(i) (blank 2)
(ii) (blank 2)
rate (blank 3)
rate constant (blank 3)
rate law (blank 3)
activation energy (blank 3)
Step A (blank 4)
Step B (blank 4)
Step 1 (blank 4) – rate law of this elementary step is rate = k [ibuprofen] [HCl]). This rate law matches the experimental rate law (rate = k [ibuprofen] [HCl]).
Step 2 (blank 4)
Step 3 (blank 4)
Step 4 (blank 4)
higher (blank 5)
lower (blank 5)
same (blank 5)

2. You can't stand warm soda so you place an unopened can of soda in your freezer for 20 minutes to get it cold. Your 12 oz. (355 ml) soda contains 39 g of sugar (fructose, $C_6H_{12}O_6$).
a. You want your soda cold but not frozen so you want to figure out the freezing point of soda. The Molarity of your soda is ___ M. Since you know Molarity is close to molality, you use Molarity instead of molality to calculate the freezing point of soda to be ___ degrees C.
Blank 1: give a number with 2 significant figures only. Do not include text.
0.61
Molarity = (39 g)(1 mole/180 g)(1/0.355 l) = 0.61 M
Blank 2: give a number with 2 significant figures only. Do not include text.
$\Delta T_f = i\, K_f\, m = (1)(1.86\ ^oC/m)(0.61\ m) = 1.1^oC$
ΔT_f = f.p. of pure solvent – f.p. of solution.
Solve for f.p. of solution = f.p. of pure solvent - $\Delta T_f = 0 - 1.1 = -1.1^oC$
So freezing point = -1.1^oC

Molality calculation:
Density of 11% fructose solution = 1.039 g/ml (https://www.engineeringtoolbox.com/density-aqueous-solution-organic-sugar-alcohol-concentration-d_1954.html)
355 ml of 11% fructose (1.039 g/ml) = 368.8 g solution
39 g fructose + __ g of water = 368.8 g solution so 329.8 g of water

molality = (39 g)(1 mole/180 g)(1/0.3298 kg) = 0.66 m. This molality of this solution is close to the Molarity so the Molarity = molality assumption is valid.
$\Delta T_f = i\ K_f\ m$ = (1)(1.86 °C/m)(0.66 m) = 1.2°C
So freezing point = -1.2°C

b. The sugar in soda ___ the freezing point because _____ makes it harder for the solvent to combine to form a solid. This means _____ energy is required to freeze the solution.
Blank 3: give a one word answer in "Other".
raises (blank 1)
lowers (blank 1)
does not change (blank 1)
higher (blank 3)
lower (blank 3)
the same (blank 3)
Other
sugar

c. After 20 minutes in the freezer, your soda is not frozen so you take the soda out of the freezer and open the can and drink a small amount of soda and put it back in the freezer. You take the soda out of the freezer after 30 minutes and you notice the soda has frozen. Explain this observation.
Carbonated soda has a higher solute concentration and lower freezing point ($\Delta T_f = i\ K_f\ m$ so ΔT_f is directly proportional to concentration) than uncarbonated (flat) soda, which has a lower solute concentration and higher freezing point.

d. You are making some home-made jam and you know sugar is used to preserve home-made jam by killing bacteria that may cause botulism. The appropriate sugar concentration will allow water to pass out of the bacteria cell and collapse (crenate) the cell. You don't have any sugar but you still have some soda.
The % sugar (mass/volume) in regular soda is ___ %(m/V). The sugar concentration that is used to preserve the jam should be ___ the sugar concentration (5%) inside the bacteria cells. This means soda ___ be used to preserve your home-made jam due to ___.
Blank 1: give a number with 2 significant figures.
11
% sugar = (39 g sugar/355 ml) x 100 = 11%
Blanks 2-4. Blank 4: give a one word answer in "Other".
higher than (blank 2)
lower than (blank 2)
same as (blank 2)
can (blank 3)
can not (blank 3)
Other
osmosis

Quiz 5 solutions
0. Reaction rate ___ as temperature increases because reactants move _____ and collisions occur with ___ energy to break or make bonds.
Check three (3) boxes.
Increases (Blank 1)
Decreases (Blank 1)
Stays the same (Blank 1)
Slower (Blank 2)
Faster (Blank 2)
same speed (Blank 2)
more (Blank 3)
less (Blank 3)

same (Blank 3)

1. You made wintergreen in Lab 1 by reacting salicylic acid ($C_7H_6O_3$) with methanol (CH_3OH). If you react salicylic acid with acetic acid ($C_2H_4O_2$), you can make aspirin ($C_9H_8O_4$):

$C_7H_6O_3 + C_2H_4O_2$ ---> $C_9H_8O_4 + H_2O$

The rate law for this reaction is: rate = k [$C_7H_6O_3$] [$C_2H_4O_2$]

The salicylic acid and acetic acid reaction is slow. Sulfuric acid, H_2SO_4, is used as a catalyst in this reaction.

The rate law for this reaction with the H_2SO_4 catalyst is: rate = k [$C_2H_4O_2$] [H_2SO_4]

If the reaction is run at 25°C instead of 70°C, the ____. The equation or formula that supports your answer is ___.

Blank 2: Write the equation in "Other". Do not give its name.

reaction rate increases, rate constant stays the same, and activation energy increases (blank 1)

reaction rate increases, rate constant decreases, and activation energy stays the same (blank 1)

reaction rate decreases, rate constant increases, and activation energy stays the same (blank 1)

reaction rate decreases, rate constant decreases, and activation energy stays the same (blank 1)

reaction rate increases, rate constant increases, and activation energy stays the same (blank 1)

Other

$k = Ae^{(-Ea/RT)}$

2. Consider the reaction: A + B --> products.

You want to determine the rate law for this reaction: Rate = k $[A]^x$ $[B]^y$.

You do four experiments to determine x, y, and k.

Experiment 1: [A] = 1 M, [B] = 10 M, rate = 10 M/sec

Experiment 2: [A] = 1 M, [B] = 20 M, rate = 40 M/ sec

Experiment 3: [A] = 2 M, [B] = 20 M, rate = 80 M/ sec

Experiment 4: [A] = 2 M, [B] = 10 M, rate = __ ? __ M/ sec

a. The data show x = __ and y = ___.

Give a number only in each blank. Do not include text. Separate each answer with a comma.

Answer: 1, 2

Keeping A constant and double B quadruples the rate so y = 2.

Double A and keep B constant doubles the rate so x = 1.

b. For Experiment 4, the rate = ____ M/sec.

Give a number only. Do not include text.

20

c. The rate constant = ____ and the units are _____.

1st blank: Give a number only. Do not include text. 2nd blank: give the units. Separate each answer with a comma.

0.1, M^{-2} sec^{-1}

Experiment 1: 10 M/sec = k $(1)(10)^2$. Solve for k = 0.1 M^{-2} sec^{-1}

Experiment 2: 40 M/sec = k $(1)(20)^2$. Solve for k = 0.1 M^{-2} sec^{-1}

Quiz 4 solutions

1. When a solute is added to a solvent, the solute makes it ____ for the solvent to escape to the gas phase. The vapor pressure of the solution ____ and ____ energy is required to boil the solution and ____ the boiling point.

easier (blank 1)

harder (blank 1)

no difference (blank 1)

increases (blank 2)

decreases (blank 2)

stays the same (blank 2)

more (blank 3)

less (blank 3)

same amount of (blank 3)

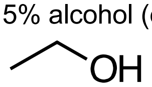
raises (blank 4)
lowers (blank 4)
does not change (blank 4)

2. A ____ m NaCl (aq) has the same boiling point as 1.0 m sucrose (aq) because _____.
1st blank: Give a number with one significant figure. 2nd blank: give your reasons. Separate your answers with a comma.
0.5, NaCl dissociates into two particles (i=2)
NaCl is an ionic compound and dissociates into 2 ions (i = 2) but sucrose is a molecular compound and does not dissociate (i = 1).

3. Sea water (0.60 M NaCl) is placed on the left side of a semipermeable membrane and pure water is placed on the right side of the membrane. As ____ passes from _____, the osmotic pressure _____ until the concentration on the left side of the membrane ____ the concentration on the right side of the membrane.
NaCl (blank 1)
Water (blank 1)
Right to left (blank 2)
Left to right (blank 2)
Increases (blank 3)
Decreases (blank 3)
Does not change (blank 3)
Is greater than (blank 4)
Is the same as (blank 4)
Is less than (blank 4)

4. You want to make ice cream. You have 1 cup (240 ml) of an ice cream mixture and know the freezing point of your ice cream mixture is -5°C. You have 750 g (about 1.5 lb) of ice. You have 250 g of $CaCl_2$.
a. You add 75 g of $CaCl_2$ to 750 g of ice. The molality of the $CaCl_2$/water solution is ___ m and the freezing point depression is ___ °C.
Blank 1: Give a number with 2 significant figures.
Blank 2: Give a number with 2 significant figures.
m = moles solute/kg solvent = 75 g $CaCl_2$ (1 mole $CaCl_2$ /111 g $CaCl_2$) (1/0.750 kg) = 0.90 m
$\Delta T_f = i\ K_f\ m$ = (3)(1.86 °C/m)(0.90 m) = 5.0°C
So freezing point = -5.0°C
b. 75 g of $CaCl_2$ to 750 g of ice ___ make my ice cream mixture freeze. I would have ____ $CaCl_2$ to the rock salt to lower the freezing point to make ice cream.
will (blank 1)
will not (blank 1)
To add more (blank 2)
To add less (blank 2)
Enough (blank 2)
As discussed in lab, an ice cream mixture with an initial temperature of room temperature that is immersed in a -5°C ice bath will not reach -5°C because the heat gained by the ice bath = the heat lost by the ice cream mixture so the final temperature of the ice cream mixture will be higher than -5°C. You want to use an ice bath with a temperature lower
than -5°C to freeze the ice cream mixture at -5°C.

Quiz 3 solutions
1. Ethanol, C_2H_5OH (density = 0.79 g/ml) is the alcohol in beer, wine, and distilled spirits. A typical beer is 5% alcohol (ethanol) by volume.



a. C_2H_5OH is ____ in water because ____ between water molecules are ____ when ethanol ____ to water.

Soluble (blank 1)
Not soluble (blank 1)
covalent bonds (blank 2)
London dispersion forces (blank 2)
hydrogen bonds (blank 2)
broken (blank 3)
cannot be broken (blank 3)
forms hydrogen bonds (blank 4)
does not form hydrogen bonds (blank 4)
b. In 12 ounces (350 ml) of beer, there are ___ grams of ethanol, __ moles of ethanol, and the molarity is ___ M.
Blank 1: Give a number with 2 significant figures only. Do not include text.
13.8
350 ml beer x (5 ml ethanol/100 ml beer) x (0.79 g ethanol/ml ethanol) = 13.8 g
Blank 2: Give a number with 2 significant figures only. Do not include text.
0.30
13.8 g (1 mole/46 g) = 0.30 moles
Blank 3: Give a number with 2 significant figures only. Do not include text.
0.86
0.30 moles/0.35 l = 0.86 M

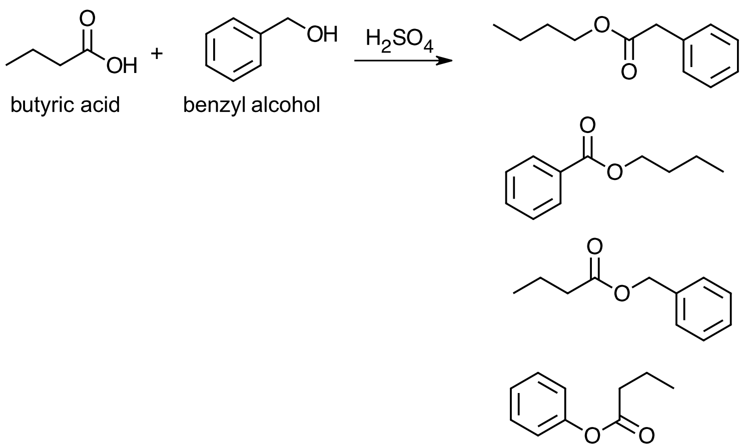
2. Calcium carbonate ($CaCO_3$) is the mineral in limestone and the active ingredient in Tums and Rolaids antacid.
a. This compound is not soluble in water because the ____ chemical forces between $CaCO_3$ and water _____ to overcome the energy to break the ____ chemical forces in $CaCO_3$.
covalent bonds (blank 1)
ionic bonds (blank 1)
ion-dipole forces (blank 1)
London dispersion (blank 1)
Absorb enough energy (blank 2)
Do not release enough energy (blank 2)
Release enough energy (blank 2)
solute-solute (blank 3)
solute-solvent (blank 3)
solvent-solvent (blank 3)

b. The ion-dipole force between CO_3^{-2} ion and water involves the ___ atom in water because this atom is less ___ than the other atom in water.
Blank 1: give the atomic symbol. Blank 2: give the property of an element. Separate each answer with a comma.
H, electronegative

3. You are heating up some water for coffee. The bubbles you see in your pot are oxygen gas. Oxygen is ____ and the ___ forces between O_2 molecules and water are ___ in hot water.
Polar (blank 1)
Non-polar (blank 1)
London dispersion (blank 2)
Dipole-dipole forces (blank 2)
Hydrogen bonds (blank 2)
Harder to break (blank 3)
Easier to break (blank 3)

Quiz 2 solutions
1. Butyric acid stinks (smells like vomit). But it reacts with benzyl alcohol to form a compound that smells like cherry.

The structure of the compound that smells like cherry is ___ because the bond that breaks in butyric acid and the bond that breaks in benzyl alcohol are _____.



A

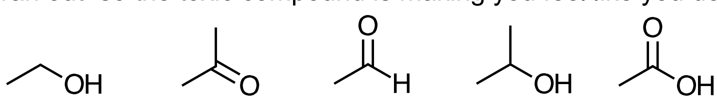
B

C

D

A (blank 1)
B (blank 1)
C (blank 1)
D (blank 1)
O-H bond in benzyl alcohol and C-O bond in butyric acid (blank 2)
C-O bond in benzyl alcohol and C=O bond in butyric acid (blank 2)
C-O bond in benzyl alcohol and C-O bond in butyric acid (blank 2)
O-H bond in benzyl alcohol and O-H bond in butyric acid (blank 2)

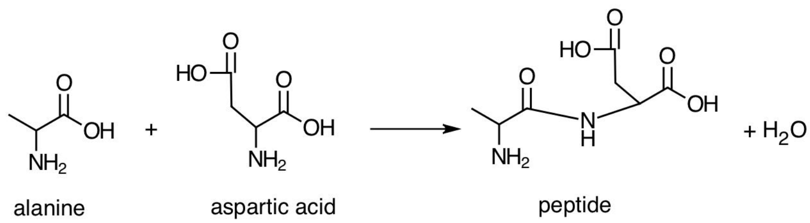
2. Your friend just turned 21 yesterday and celebrated with too much alcohol and isn't feeling so good today. You explain, "the ethanol is ___ with the help of an enzyme to compound _____, which is toxic, and then another enzyme converts this toxic compound to ___. You drank too much and the second enzyme ran out so the toxic compound is making you feel like you do."



A B C D E

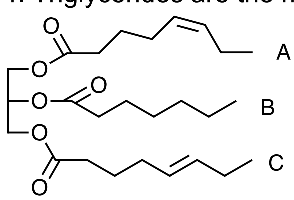
Blank 1: give a one word answer in "Other". Check your spelling.
A (blank 2)
B (blank 2)
C (blank 2)
D (blank 2)
E (blank 2)
A (blank 3)
B (blank 3)
C (blank 3)
D (blank 3)
E (blank 3)
Other
Oxidized
Ethanol is a primary (1°) alcohol and is oxidized to an aldehyde (Compound C acetaldehyde (toxic!)), which is further oxidized to an acid (Compound E acetic acid).

3. Alanine reacts with aspartic acid to form a peptide. A peptide is a chain of amino acids. A peptide bond is the bond that connects the amino acids together.
In the peptide shown below, the peptide bond is the ______ which is part of the ____ functional group.



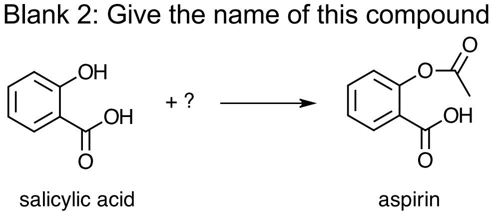
C-C bond (blank 1)
C-H bond (blank 1)
C-N bond with C in double bond with O (blank 1)
C-N bond with C bonded to C (blank 1)
C=O bond (blank 1)
Acid (blank 2)
Alcohol (blank 2)
Amide (blank 2)
Amine (blank 2)

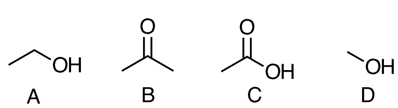
4. Triglycerides are the main component of body fat.



The fatty acid chain that can not undergo hydrogenation is/are _____. The trans fat is ____.
Check the boxes that apply.
A (blank 1)
B (blank 1)
C (blank 1)
A (blank 2)
B (blank 2)
C (blank 2)
Chain B does not contain any C=C bonds (it is a saturated fat) and does not undergo hydrogenation.
Chain A is a cis fat. Chain C is a trans fat.

5. Salicylic acid is used to make aspirin and wintergreen. The compound that reacts with salicylic acid to make aspirin is ___. The 2nd product of this reaction is ___.
Blank 2: Give the name of this compound (one word) in “Other”.



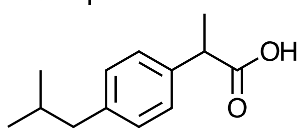


A (blank 1)
B (blank 1)
C (blank 1)
D (blank 1)
Other
Water

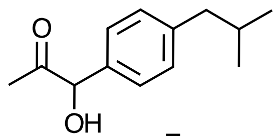
Salicylic acid contains three functional groups – alcohol, acid, and aromatic. The alcohol group in salicylic acid reacts with acetic acid to produce aspirin.

Quiz 1 solutions
1. Some people relax after a long day with an alcoholic beverage. Alcohol (ethanol) is produced by fermenting sugar (glucose): $C_6H_{12}O_6$ ---> 2 C_2H_5OH + 2 CO_2.
a. Starting with 2.5 moles of glucose (1.0 pounds), what conversions would you do to calculate the theoretical yield of ethanol in g? Check the boxes that apply.
Mass of glucose to volume of glucose
Mass of glucose to moles of glucose
Moles of glucose to moles of ethanol
Moles of glucose to moles of carbon dioxide
Moles of ethanol to mass of ethanol
b. Starting with 2.5 moles of glucose (1.0 pounds), calculate the theoretical yield of ethanol in g. Give a number with 2 significant figures only; do not include text.
2.5 moles glucose (2 moles ethanol/1 mole glucose)(46 g ethanol/1 mole ethanol) = 230 g

2. Compare Structure Z and ibuprofen.



Ibuprofen



Z

a. The name of the functional group in Ibuprofen with the C=C bonds is ___. The name of the functional group in Ibuprofen with the C=O bond is ____.
Acid (blank 1)
Alcohol (blank 1)
Aldehyde (blank 1)
Aromatic (blank 1)
Ester (blank 1)
Ether (blank 1)
Ketone (blank 1)
Acid (blank 2)
Alcohol (blank 2)
Aldehyde (blank 2)
Aromatic (blank 2)
Ester (blank 2)
Ether (blank 2)
Ketone (blank 2)

b. Structure Z has ___ carbons. Ibuprofen has ___ hydrogens.
Blank 1: Give a number only. Do not include text. Blank 2: Give a number only. Do not include text. Separate each answer with a comma.
13, 18
c. These compounds are ___ because ___.
Blank 2: give reasons in "Other".
same compound (blank 1)
isomers (blank 1)
different compounds (blank 1)
Other
same chemical formula ($C_{13}H_{18}O_2$) but different bonding