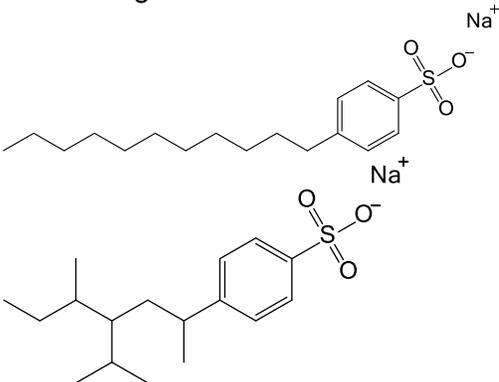# Activity 3 Print Files
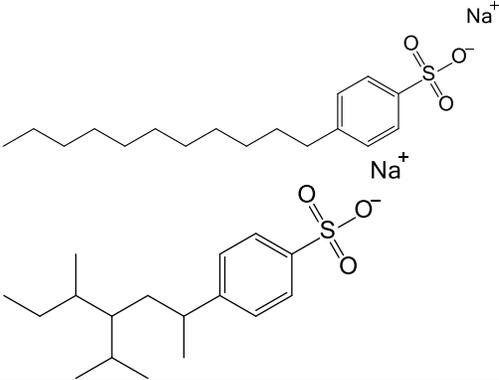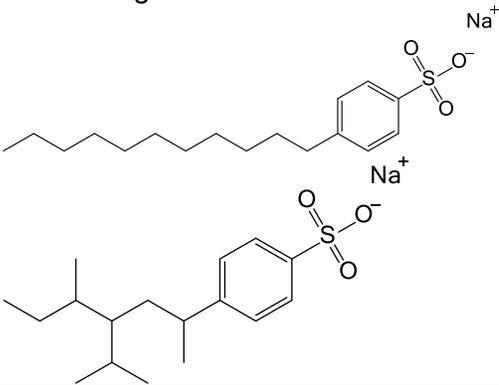
Activity 3 – Keywords: A waste and hazard reduction puzzle

Question	Response	Team/Group	Letter	Colour Dots
What is the expression that defines E-factor?	Kg waste/Kg product	1	G	Green
What is the expression that defines E-factor?	Kg waste/Kg product	2	G	Blue
What is the expression that defines E-factor?	Kg waste/Kg product	3	C	Yellow
What is the expression that defines E-factor?	Kg waste/Kg product	4	H	Red
LD50 is a metric on chemical SDS pages, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the following LD50 data; determine which of these compounds is the most toxic? <table><tr><td>Potassium Hydroxide</td><td>ORAL 333 mg/kg (rat, male)</td></tr><tr><td>Ammonium</td><td>ORAL 350 mg/kg (rat)</td></tr><tr><td>Potassium Carbonate (anhydrous)</td><td>ORAL 2000 mg/kg (rat, male and female)</td></tr><tr><td>Triethylamine</td><td>ORAL 460 mg/kg (rat)</td></tr></table>	Potassium Hydroxide	1	O	Green
LD50 is a metric on chemical SDS pages, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the following LD50 data; determine which of these compounds is the most toxic? <table><tr><td>Hydrochloric acid</td><td>ORAL 238 mg/kg (rat)</td></tr><tr><td>Formic acid</td><td>ORAL 738 mg/kg (rat)</td></tr><tr><td>Glacial acetic acid</td><td>ORAL 3310 mg/kg (rat)</td></tr><tr><td>Citric acid</td><td>ORAL 6730 mg/kg (rat)</td></tr></table>	Hydrochloric acid	2	R	Blue
LD50 is a metric on chemical SDS pages, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the following LD50 data; determine which of these compounds is the least toxic? <table><tr><td>Potassium Hydroxide</td><td>ORAL 333 mg/kg (rat, male)</td></tr><tr><td>Ammonium</td><td>ORAL 350 mg/kg (rat)</td></tr><tr><td>Potassium Carbonate (anhydrous)</td><td>ORAL 2000 mg/kg (rat, male and female)</td></tr><tr><td>Triethylamine</td><td>ORAL 460 mg/kg (rat)</td></tr></table>	Potassium Carbonate (anhydrous)	3	O	Yellow

Question	Answer	Number	Letter	Color
LD50 is a metric on chemical SDS pages, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the following LD50 data; determine which of these compounds is the least toxic? <table><tr><td>Hydrochloric acid</td><td>ORAL 238 mg/kg (rat)</td></tr><tr><td>Formic acid</td><td>ORAL 738 mg/kg (rat)</td></tr><tr><td>Glacial acetic acid</td><td>ORAL 3310 mg/kg (rat)</td></tr><tr><td>Citric acid</td><td>ORAL 6730 mg/kg (rat)</td></tr></table>	Citric acid	4	I	**Red**
What is one advantage of using water as a solvent in a reaction at a temperature below 100°C?	Minimal VOC emissions generated from reaction	1	F	**Green**
What is one disadvantage of using water as a solvent in a reaction at a temperature below 100°C?	Limits reaction to only utilizing reactants that are air- and water-stable	2	E	**Blue**
What is one advantage of using water as a solvent in a reaction at a temperature below 100°C?	Lowers the cost of the reaction	3	O	**Yellow**
What is one disadvantage of using water as a solvent in a reaction at a temperature below 100°C?	Product could be difficult to isolate due to costs of separation, distillation or boiling off solvent	4	N	**Red**
Which of the reactions on page 36 of the handbook has the **highest** turnover number?	Product 6	1	O	**Green**
Which of the reactions on page 37 of the handbook has the **highest** turnover number?	Product 7	2	E	**Blue**
Which of the reactions on page 36 of the handbook has the **lowest** turnover number?	Product 3	3	L	**Yellow**
Which of the reactions on page 37 of the handbook has the **lowest** turnover number?	Product 4	4	D	**Red**
Which of these two compounds has a **slower** degradation rate?	Linear product	1	R	**Green**

Which of these two compounds has a **faster** degradation rate?	Branched product	2	N	**Blue**	
Which of these two compounds has a **slower** degradation rate?	Linear product	3	C	<mark>Yellow</mark>	
Which of these two compounds has a **faster** degradation rate?	Branched product	4	E	**Red**	
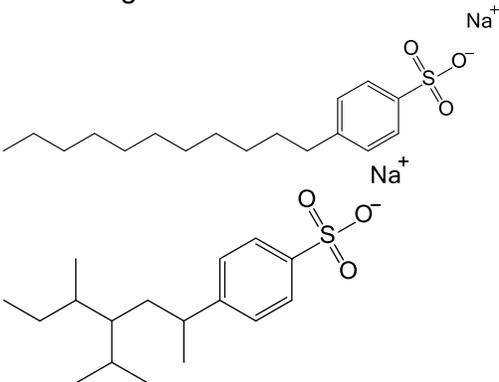
Question	Answer	Number	Letter	Colour

Which of these processes will have a lower E-factor?
   a. Cumene route to phenol (scheme 1.1)
   b. Sulfonation route to phenol (scheme 1.2)
	Cumene route to phenol	1	G	**Green**

Which of these processes will have a higher E-factor?
   a. Cumene route to phenol (scheme 1.1)
   b. Sulfonation route to phenol (scheme 1.2)
	Sulfonation route to phenol	2	E	**Blue**

Which of these processes will have a lower E-factor?
   a. Current pathway to Ibuprofen (scheme 2.1)
   b. Boots pathway to Ibuprofen (scheme 2.2)
	Current pathway to Ibuprofen	3	A	<mark>Yellow</mark>

Which of these processes will have a higher E-factor?
   a. Current pathway to Ibuprofen (scheme 2.1)
   b. Boots pathway to Ibuprofen (scheme 2.2)
	Boots pathway to Ibuprofen	4	R	**Red**

Identify one of the by-products from the reaction scheme 1.1 (handbook page 39)	CO_2	1	R	**Green**
Identify one of the by-products from the reaction scheme 1.1 (handbook page 39)	Na_2SO_3	2	R	**Blue**
Identify one of the by-products from the reaction scheme 2.1 (handbook page 40)	$Al(OH)_3$	3	T	<mark>Yellow</mark>
Identify one of the by-products from the reaction scheme 2.1 (handbook page 40)	C_2H_5OH	4	H	**Red**
Using the information in the handbook - which of these metals is the most abundant on earth? Chromium (Cr), Titanium (Ti), Gold (Au), Gallium (Ga)	Ti	1	E	**Green**
Using the information in the handbook - which of these metals is the most abundant on earth? Ruthenium (Ru), Nickel (Ni), Iron (Fe), Zinc (Zn)	Fe	2	C	**Blue**
Using the information in the handbook - which of these metals is the most abundant on earth? Chromium (Cr), Titanium (Ti) Gold (Au), Gallium (Ga)	Ga	3	A	<mark>Yellow</mark>
Using the information in the handbook - which of these metals is the most abundant on earth? Ruthenium (Ru), Nickel (Ni) Iron (Fe), Zinc (Zn)	Zn	4	A	**Red**

Question	Answer			
What does a reaction run "neat" mean?	A reaction is performed in which a reactant is in a liquid state at the temperature of the reaction, and behaves as a solvent for other reactants.	1	E	**Green**
What does a reaction run "neat" mean?	A reaction is performed in which a reactant is in a liquid state at the temperature of the reaction, and behaves as a solvent for other reactants.	2	H	**Blue**
How can a reaction be run without the use of a solvent?	Mechanochemistry - using the kinetic energy of either ball-milling or mortar and pestle to break and form bonds	3	L	**Yellow**
How can a reaction be run without the use of a solvent?	Running a reaction "neat" - a reactant is a liquid at the temperature of the reaction and acts as a solvent for other reactants	4	Z	**Red**
Using the handout provided, on page 41 and 42, find a reaction that has generates no by-product and has an atom economy of 100%	Claisen rearrangement	1	N	**Green**
Using the handout provided, on page 41 and 42, find a reaction that has generates no by-product and has an atom economy of 100%	Beckmann rearrangement	2	E	**Blue**
Using the handout provided, on page 41 and 42, find a reaction that has generates no by-product and has an atom economy of 100%	Claisen rearrangement	3	Y	**Yellow**
Using the handout provided, on page 41 and 42, find a reaction that has generates no by-product and has an atom economy of 100%	Beckmann rearrangement	4	A	**Red**
Listed are the flash points of 4 solvents. Which solvent poses the **largest** fire risk if it were to be used? Solvents / Flash point (°C): Methanol 9.7, Ethanol 13, Isopropanol 12, Ethyl acetate -4, Acetone -17	Acetone	1	E	**Green**
Listed are the flash points of 4 solvents. Which solvent poses the **largest** fire risk if it were to be used? Solvents / Flash point (°C): Methanol 9.7, Ethanol 13, Isopropanol 12, Ethyl acetate -4, Acetone -17	Ethanol	2	M	**Blue**

Question	Answer			
Listed are the flash points of 4 solvents. Which solvent poses the **least** fire risk if it were to be used? 	Solvents	Flash point (°C)
---	---
Methanol	9.7
Ethanol	13
Isopropanol	12
Ethyl acetate	-4
Acetone	-17		Acetone	3	S	Yellow
Listed are the flash points of 4 solvents. Which solvent poses the **least** fire risk if it were to be used? 	Solvents	Flash point (°C)
---	---
Methanol	9.7
Ethanol	13
Isopropanol	12
Ethyl acetate	-4
Acetone	-17		Ethanol	4	R	Red
Which of these reactions will have the greater percent atom economy? | A + B → C C + X → Y	A + B → C + D C + X →Y		A + B → C C + X → Y	1	R	Green
Which of these reactions will have the lesser percent atom economy? | A + B → C C + X → Y	A + B → C + D C + X →Y		A + B → C + D C + X →Y	3	T	Blue
Blank Question	Blank answer	4	D	No colour given, but will be with team with **Red** answers

Activity 4 Questions

What is the expression that defines E-factor?
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What is the expression that defines E-factor?

LD50 is a metric on a chemical's SDS, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the LD50 data below (also on page 35 of the handbook, and the handout for this activity), determine which compound is the **MOST** dangerous if ingested?

Potassium Hydroxide	ORAL 333 mg/kg (rat, male)
Ammonium	ORAL 350 mg/kg (rat)
Potassium Carbonate (anhydrous)	ORAL 2000 mg/kg (rat, male and female)
Triethylamine	ORAL 460 mg/kg (rat)

What is one advantage of using water as a solvent in a reaction at a temperature below 100°C?

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LD50 is a metric on a chemical's SDS, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the LD50 data below (also on page 35 of the handbook, and the handout for this activity), determine which compound is the **MOST** dangerous if ingested?

Potassium Hydroxide	ORAL 333 mg/kg (rat, male)
Ammonium	ORAL 350 mg/kg (rat)
Potassium Carbonate (anhydrous)	ORAL 2000 mg/kg (rat, male and female)
Triethylamine	ORAL 460 mg/kg (rat)

LD50 is a metric on a chemical's SDS, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the LD50 data below (also on page 35 of the handbook, and the handout for this activity), determine which compound is the **MOST** dangerous if ingested?

Hydrochloric acid	ORAL 238 mg/kg (rat)
Formic acid	ORAL 738 mg/kg (rat)
Glacial acetic acid	ORAL 3310 mg/kg (rat)
Citric acid	ORAL 6730 mg/kg (rat)

LD50 is a metric on a chemical's SDS, which is a measure that determines the dosage of that chemical that is lethal to 50% of a population. Using the LD50 data below (also on page 35 of the handbook, and the handout for this activity), determine which compound is the **MOST** dangerous if ingested?

| Hydrochloric acid	ORAL 238 mg/kg (rat)
Formic acid	ORAL 738 mg/kg (rat)
Glacial acetic acid	ORAL 3310 mg/kg (rat)
Citric acid	ORAL 6730 mg/kg (rat)

Which of the reactions on page 36 of the handbook has the **highest** turnover number?

Which of the reactions on page 37 of the handbook has the **highest** turnover number?
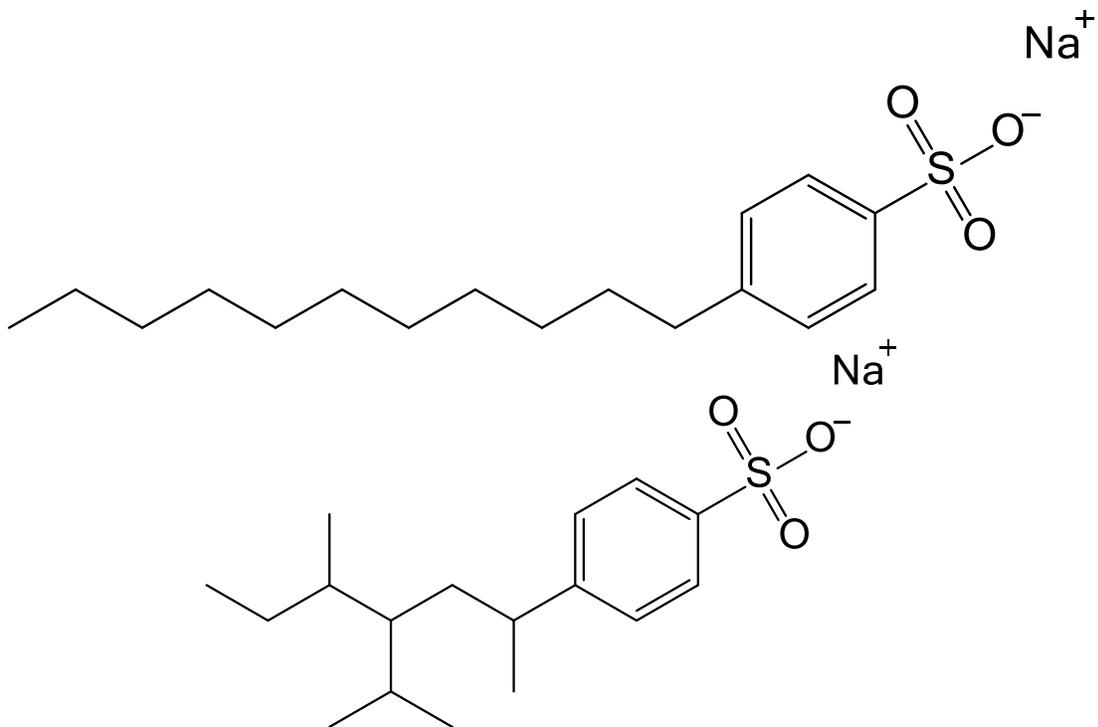
Which of the reactions on page 36 of the handbook has the **lowest** turnover number?

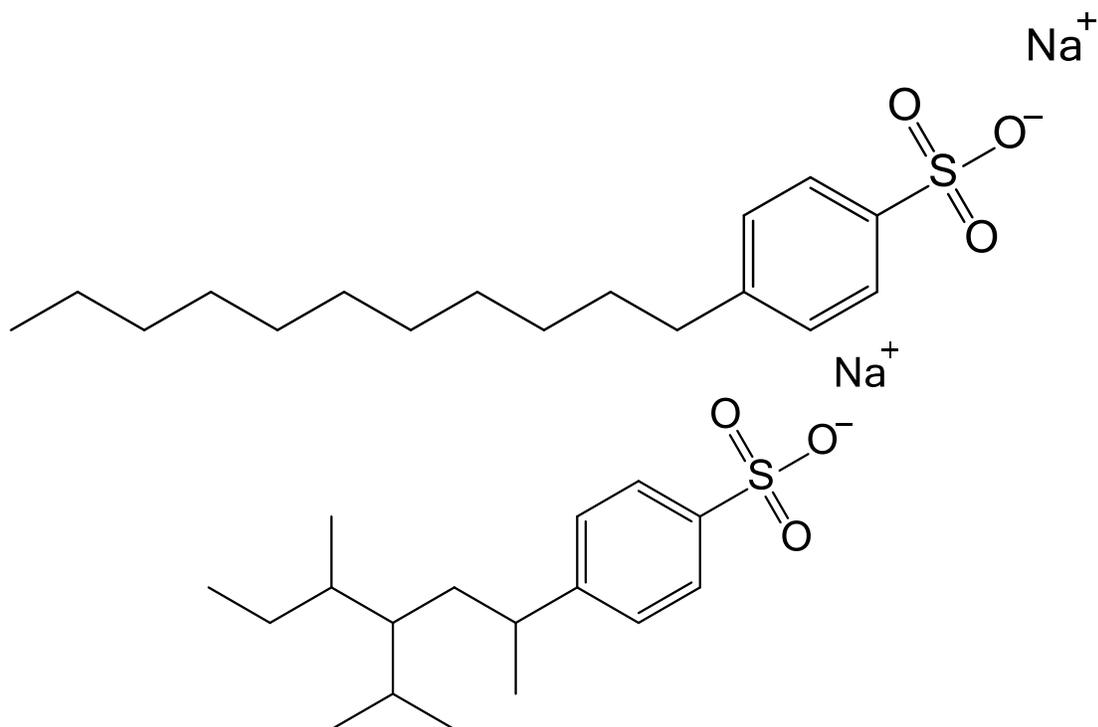Which of the reactions on page 37 of the handbook has the **lowest** turnover number?

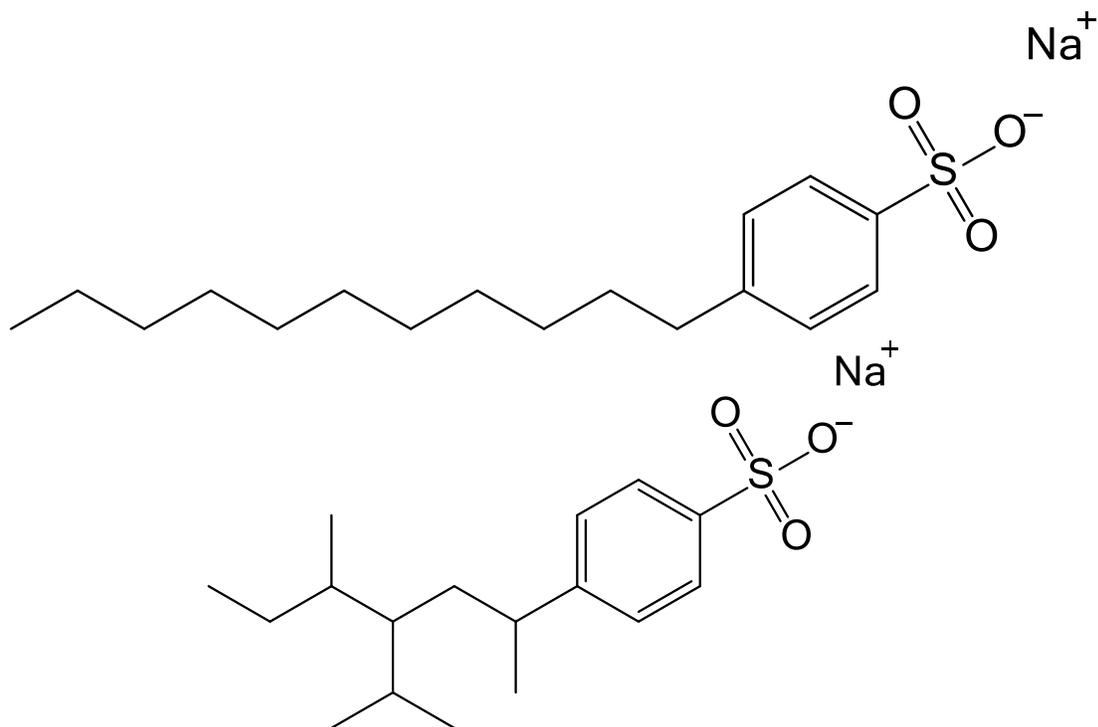# Which of these two compounds has a faster degradation rate?
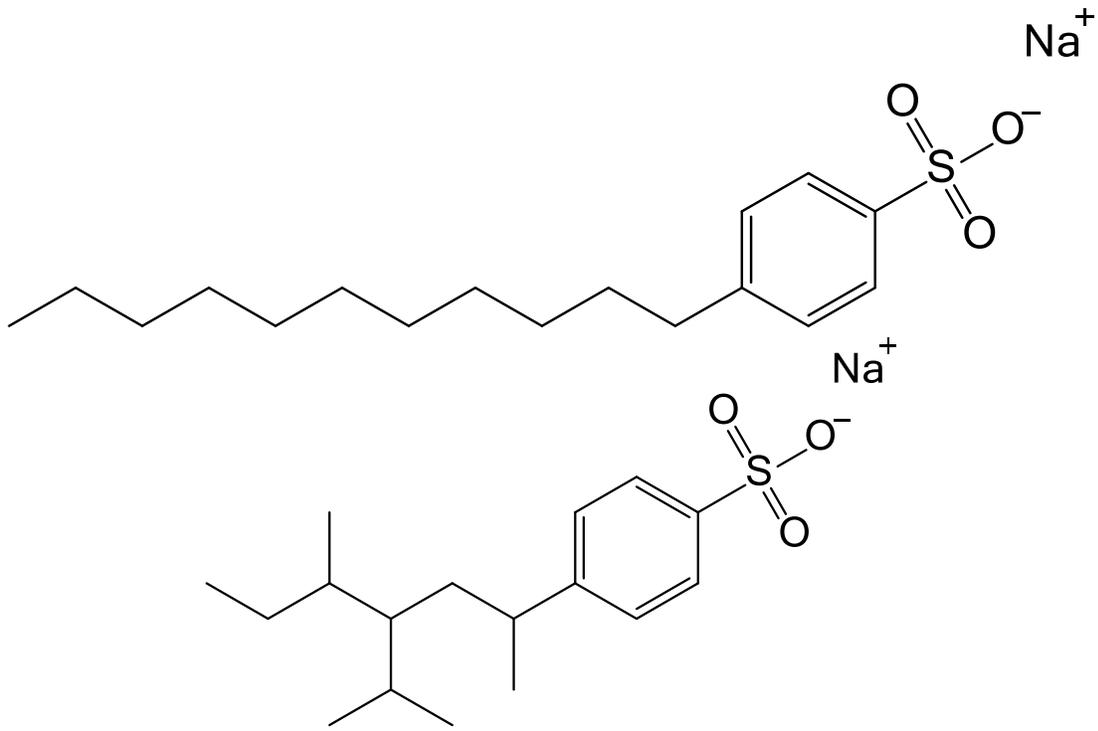
Which of these two compounds has a faster degradation rate?

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Which of these two compounds has a faster degradation rate?

See page 39 in the handbook or activity handout. Which of these processes (scheme 1.1 or 1.2) will have a lower E-factor? a. Cumene route to phenol (scheme 1.1) b. Sulfonation route to phenol (scheme 1.2)
See page 39 in the handbook or activity handout. Which of these processes (scheme 1.1 or 1.2) will have a lower E-factor? a. Cumene route to phenol (scheme 1.1) b. Sulfonation route to phenol (scheme 1.2)
See page 40 in the handbook or activity handout. Which of these processes (scheme 2.1 or 2.2) will have a higher E-factor? a. Current pathway to Ibuprofen (scheme 2.1) b. Boots pathway to Ibuprofen (scheme 2.2)
See page 40 in the handbook or activity handout. Which of these processes (scheme 2.1 or 2.2) will have a lower E-factor? a. Current pathway to Ibuprofen (scheme 2.1) b. Boots pathway to Ibuprofen (scheme 2.2)
Identify one of the by-products from the reaction scheme 1.1 (handbook page 39)
Identify one of the by-products from the reaction scheme 1.1 (handbook page 39)

Identify one of the by-products from the reaction scheme 2.1 (handbook page 40)
Identify one of the by-products from the reaction scheme 2.1 (handbook page 40)
Using the information in the handbook - which of these metals is the most abundant on earth? Chromium (Cr), Titanium (Ti), Gold (Au), Gallium (Ga)
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What does a reaction run "neat" mean?
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Listed are the flash points of 5 common solvents. Which solvent poses the **largest** fire risk if it were to be used?

Solvents	Flash point (°C)
Methanol	9.7
Ethanol	13
Isopropanol	12
Ethyl acetate	-4
Acetone	-17

Listed are the flash points of 5 common solvents. Which solvent poses the **largest** fire risk if it were to be used?

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Solvents	Flash point (°C)
Methanol	9.7
Ethanol	13
Isopropanol	12
Ethyl acetate	-4
Acetone	-17

Which of these reactions will have the greater percent atom economy?

A + B → C C + X → Y	A + B → C + D C + X →Y

Which of these reactions will have the greater percent atom economy?

A + B → C C + X → Y	A + B → C + D C + X →Y

Activity 4 Answers

Kg waste/Kg product	Kg waste/Kg product
Kg waste/Kg product	Kg waste/Kg product

Hydrochloric acid	Potassium Hydroxide
Potassium Carbonate (anhydrous)	Citric Acid

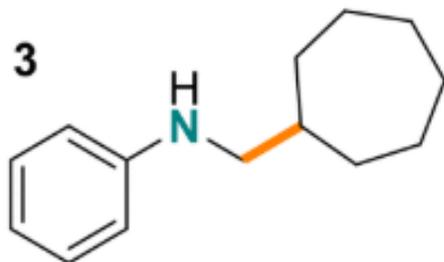|	
Minimal VOC emissions generated from reaction	Limits the reaction to utilizing reactants that are water-stable (and, usually air-stable)
Lowers cost of reaction	Product could be difficult to isolate based on solubility

Product 6

6
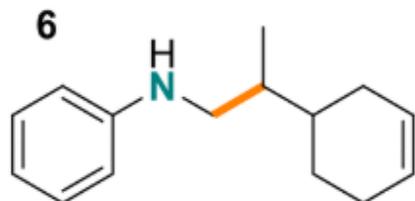
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Product 7

7
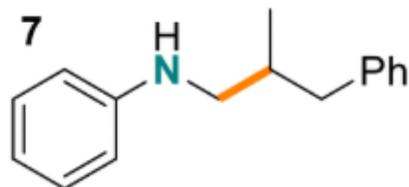
10%
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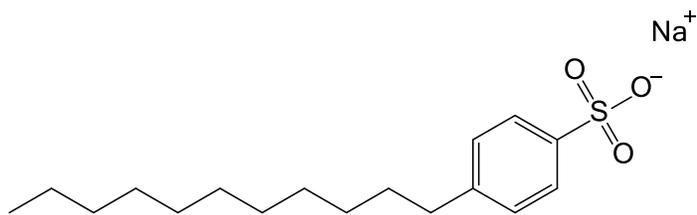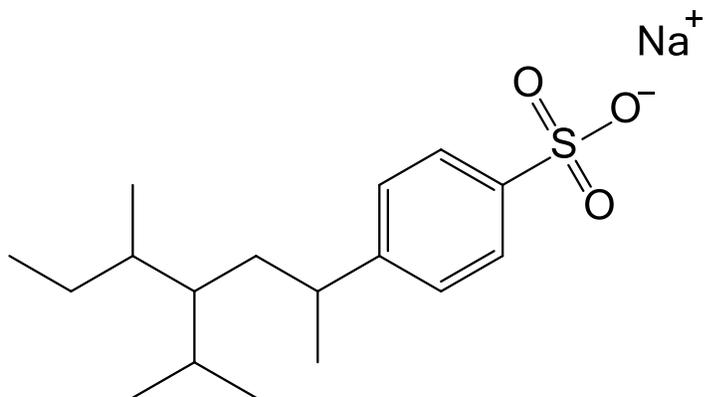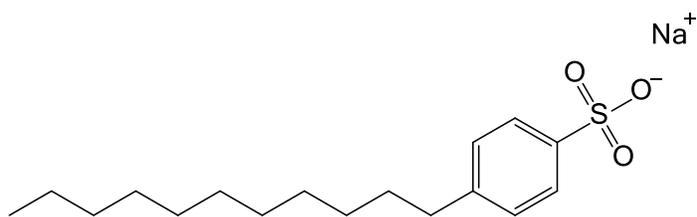
Product 3

3

10%
48 h
91%

Product 4

4
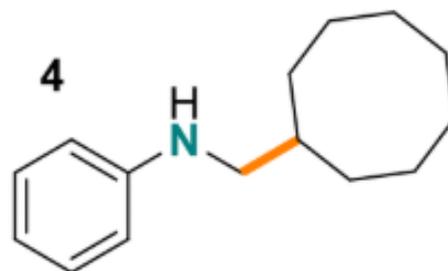
10%
48 h
78%

Activity 4 – Questions and Answers Print-off document
Refer to question and answer document for allocation of Q → A → Letter → Team
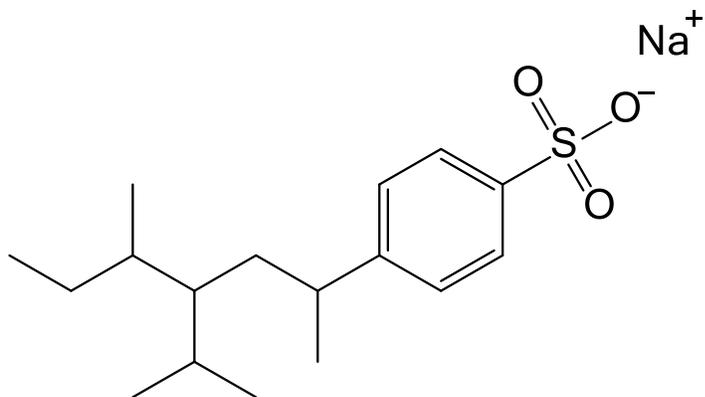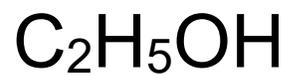
Sulfonation route to phenol synthesis	Cumene route to phenol synthesis
Current process for Ibuprofen synthesis	Boots process for Ibuprofen synthesis

CO_2	Na_2SO_3
$Al(OH)_3$	C_2H_5OH

Ti	Fe
Zn	Ga

A reaction is performed in which a reactant is in a liquid state at the temperature of the reaction, and is used as a solvent for other reactants

A reaction is performed in which a reactant is in a liquid state at the temperature of the reaction, and behaves as a solvent for other reactants

Mechanochemistry - using the kinetic energy of either ball-milling or mortar and pestle to break and form bonds

Running a reaction "neat" - a reactant is a liquid at the temperature of the reaction and acts as a solvent for other reactants

Claisen rearrangement	Beckmann rearrangement
Claisen rearrangement	Beckmann rearrangement

Acetone	Acetone
Ethanol	Ethanol

Activity 4 – Questions and Answers Print-off document
Refer to question and answer document for allocation of Q → A → Letter → Team

A + B → C C + X → Y	A + B → C + D C + X →Y