

What is green chemistry?: teacher's notes

Yield

When discussing yield, teachers may wish to comment on contrasts between different sectors of the chemical industry. The oil industry for example may be thought of as a high volume / low cost operation with many of its processes operating at high yields (often approaching) 99%, while overall yields for processes in the pharmaceutical industry are typically much lower, sometimes as low as 50%. This is sustainable because the selling prices per kilogram of pharmaceutical products are much greater than those for petroleum products.

Atom economy

The example chosen of the formation of N-methylpropanamide is unlikely to be familiar to students. It has been chosen to show the generality of the atom economy approach.

Ibuprofen

The use of ibuprofen as an example of a drug sold as a racemic mixture could lead nicely into *Ibuprofen – a case study in green chemistry*.

Answers to questions

Q 1. (a) 33%

(b) 10%

Q 2. Using more (strictly, an increased concentration) of one of the reactants would have the effect of pushing the equilibrium position to the side of products. It might also be used to speed up the reaction.

Q 3. (a) 1

(b) (i) 60

(ii) 40

(c) Sodium hydroxide

(d) Ethanoic acid

(e) 4.1 g

(f) 87.8%

Q 4. (a) 2

(b) (i) 98

(ii) 40

(c) Sodium hydroxide

(d) Sodium hydroxide

(e) 7.1 g

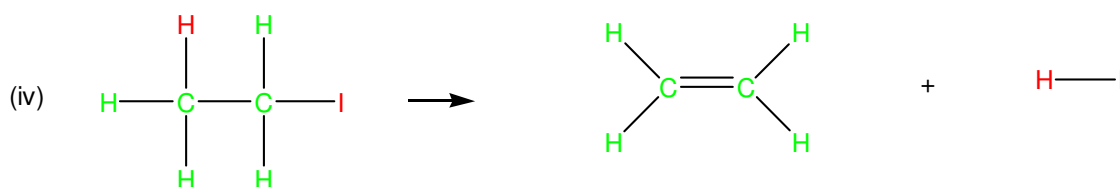
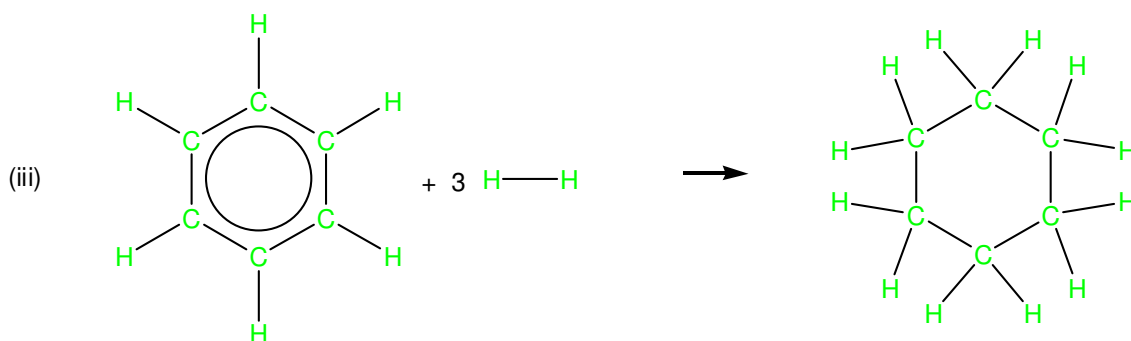
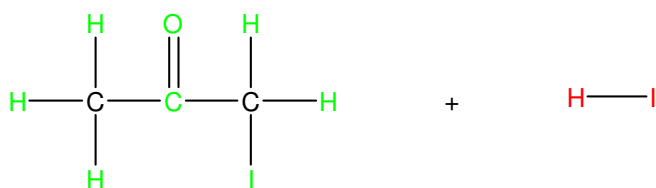
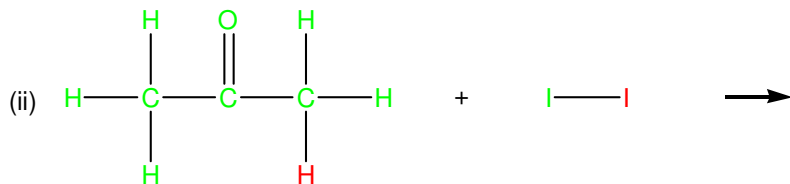
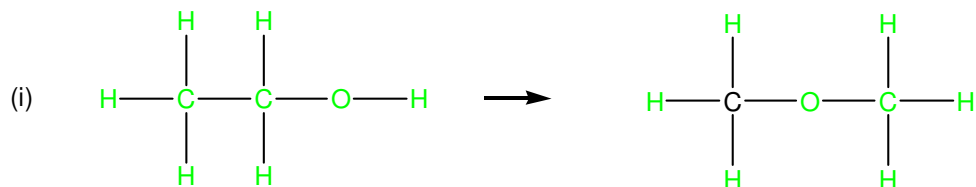
(f) 70.4%

Q 5. (a) $\text{C}_2\text{H}_5\text{OH} + [\text{O}] \rightarrow \text{CH}_3\text{CHO} + \text{H}_2\text{O}$

(b) Ethanoic acid.

(c) Some of the ethanal will be further oxidised to ethanoic acid, reducing the yield of the aldehyde.

- Q 6. The law of conservation of mass says that the total mass of the starting materials is the same as the total mass of the products.
- Q 7. (a) $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{NH}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CONHCH}_3 + \text{H}_2\text{O}$
 (b) (i) Water
 (ii) Two atoms of hydrogen and one atom of oxygen.
 (c) The atom economy will be greater because a lighter molecule has been disposed of.
 (d) 82.9%
- Q 8. (a) $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$
 (b) 83.0%
 (c) The atom economy is greater because a lighter molecule is being discarded.
 (d) The reaction does not go to completion and it is much slower.
- Q 9. (a) Step 1: Dehydrate propan-1-ol by heating over an alumina catalyst to form propene
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O}$
 Step 2: Add H-OH across the double bond of propene by treating it with concentrated sulfuric acid and then water. Markovnikov's rule predicts that propan-2-ol will be the main product.
 $\text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CHOHCH}_3$
 (b) Two steps rather than one will tend to decrease the overall yield because there are two separation and work-up processes. The overall yield is found by multiplying together the yields of each step. So if each step had a 90% yield, the overall yield would be 81%.
- Q 10. (a) Names:
 (i) ethanol, methoxymethane (no waste);
 (ii) propanone, iodopropanone (one atom of hydrogen, one atom of iodine);
 (iii) benzene, cyclohexane (no waste);
 (iv) iodoethane, ethane (one atom of hydrogen, one atom of iodine).



- (b) (i) 100%,
(ii) 59.0%,
(iii) 100%,
(iv) 17.9%

- (c) (i) re-arrangement
(ii) substitution
(iii) addition
(iv) elimination.

- (d) (i) Use a lighter halide such as bromide, chloride, fluoride.
(ii) Answer depends on the halide suggested: 25.5% for Br, 43.4% for Cl and 58.3% for F.

Q 11. (a) 100%

(b) Less than 100% because it will not go to completion.

Q 12. (1) substitution (2) elimination.

Q 13. (a) (i) $\text{CH}_2=\text{CHCH}_2\text{CH}_2\text{OH}$ (only the CHO is reduced)

(ii) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (both the CHO and $\text{C}=\text{C}$ functional groups are reduced).

(b) (i) $\text{C}=\text{O}$

(ii) $\text{C}^{\delta+}=\text{O}^{\delta-}$

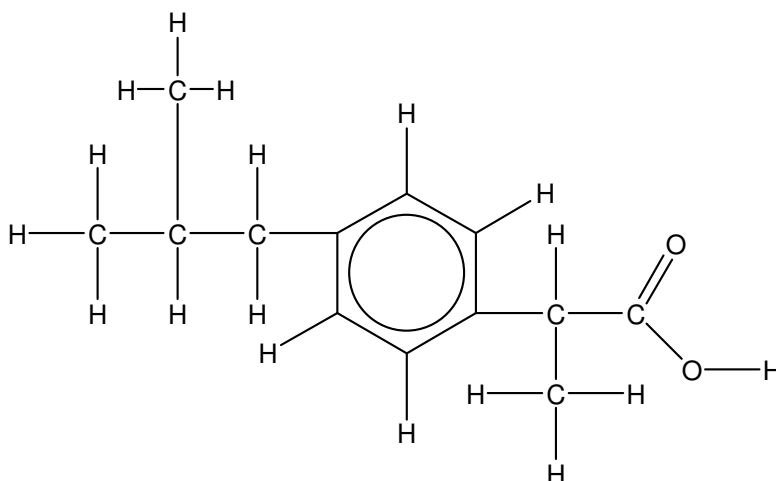
(iii) H^- will attack $\text{C}^{\delta+}$ due to its polarity. There is no polar 'handle' on $\text{C}=\text{C}$.

(iv) Yes it will, as $-\text{C}\equiv\text{N}$ is also polar ($-\text{C}^{\delta+}\equiv\text{N}^{\delta-}$).

Q 14. (a) 1-bromopropane and 2-bromopropane.

(b) 2-bromopropane will predominate.

Q 15. (a)



(b)

