

# ATOM ECONOMY

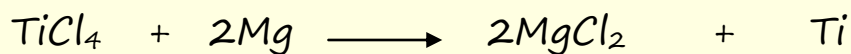


Answer the following questions then check your answers.

1. What is atom economy?
2. The Kroll process is used to extract titanium metal from its ore. An equation for this process is shown below.

( $A_r$  information Ti=48 Mg=24 Cl=35.5)

Titanium chloride + magnesium  $\longrightarrow$  magnesium chloride + titanium

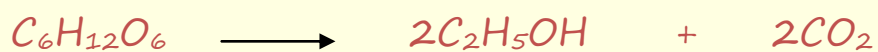


- a. Calculate the atom economy for this reaction.

2. Ethanol is made by fermenting glucose according to the equation below:

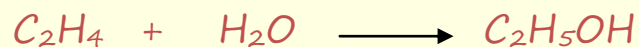
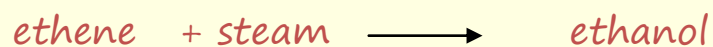
$A_r$  information C=12 H=1 O=16

glucose  $\longrightarrow$  ethanol + carbon dioxide



- a. Calculate the atom economy for this reaction.

b. Ethanol can also be made by hydrating ethene with steam. This reaction is shown below:



c. Calculate the atom economy for this reaction

d. Suggest with reasons whether fermentation or direct hydration reaction should be used to produce ethanol.

## Answers

1. What is atom economy?

Answer: It is a measure of how much of the reactants end up in a useful product.

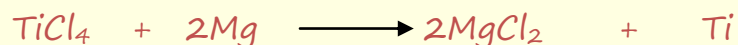
It is calculated using the formula below:

$$\% \text{ atom economy} = \frac{M_r \text{ of useful product}}{\text{sum of } M_r \text{ of all reactants}} \times 100\%$$

2. The Kroll process is used to extract titanium metal from its ore. An equation for this process is shown below.

( $A_r$  information Ti=48 Mg=24 Cl=35.5)

Titanium chloride + magnesium  $\longrightarrow$  magnesium chloride + titanium



a. Calculate the atom economy for this reaction.

$M_r$  of all reactants

$$M_r \text{ of TiCl}_4 = 48 + 142 = 190$$

$$M_r \text{ of Mg } \times 2 = 24 \times 2 = 48$$

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$$M_r \text{ of all reactants} = 238$$

$M_r$  of useful product (Ti)

$$M_r \text{ of Ti} = 48$$

$$\text{Atom economy} = 48/238 \times 100\% = 20\%$$

2. Ethanol is made by fermenting glucose according to the equation below:

(Ar information C=12 H=1 O=16)

glucose  $\longrightarrow$  ethanol + carbon dioxide



a. Calculate the atom economy for this reaction.

$M_r$  of all reactants

$M_r$  of glucose = 180

$M_r$  of useful product (ethanol)

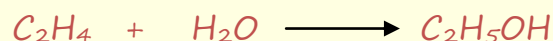
$M_r$  of ethanol =  $46 \times 2 = 92$

Atom economy =  $92/180 \times 100\% = 51\%$

b. Ethanol can also be made by hydrating ethene with steam. This reaction is shown below:

No calculations are really necessary since there is only one product the atom economy is 100%, however the calculation to work out the atom economy for this reaction are shown below:

ethene + steam  $\longrightarrow$  ethanol



c. Calculate the atom economy for this reaction

$M_r$  of all reactants

$M_r$  of ethene = 28

$M_r$  of steam = 18

$M_r$  of useful product (ethanol)

$M_r$  of ethanol = 46

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$M_r$  of all reactants =  $18 + 28 = 46$

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Atom economy =  $46/46 \times 100\% = 100\%$

c. Suggest with reasons whether fermentation or direct hydration reaction should be used to produce ethanol.

Hydration of ethene has a much higher atom economy, 100% versus 51%. It produces no waste and gives a 100% conversion rate of reactants into products with no waste and no separation problems.