

1. **Any FOUR from:**

catalyst not used up in reaction ✓

reactions take place at lower temperatures ✓

with lower energy demand **OR** lower activation energy **OR** use less fuel ✓

so less carbon dioxide emitted into atmosphere **OR** so fossil fuels last longer ✓

different reactions can be used ✓

with better atom economy **OR** less waste ✓

less hazardous chemicals ✓

catalysts or enzymes can generate specific products ✓

*ALLOW catalysts can work at room temperature **OR** enzymes work at room temperature*

***IGNORE cheaper***

[4]

2. **Availability of starting materials:**

availability

sugar is renewable because it can be grown (1)

ethane is finite because it is obtained by processing of crude oil (1)

energy:

fermentation: energy is required for distillation/

hydration: energy is required to generate steam (1)

**atom economy and waste products:**

atom economy for fermentation < atom economy hydration (1)

In fermentation, CO<sub>2</sub> is produced in addition to ethanol/ethanol is not the only product (1)

**In hydration, ethanol is the only product/hydration is an addition reaction (1)**

**Atom economy of fermentation could be increased by finding a use CO<sub>2</sub> (1)**



Atom economy linked to a chemical equation to show that hydration has 100% atom economy/fermentation has 51% atom economy (1) 7max

[7]

3. (i)  $M_r C_7H_{16} = 100$  (1)

amount =  $2000/100 = 20$  mol (1) 2

(ii) energy saved =  $20 \times 4817 = 9634$  kJ (1) 1

(iii) moles CO<sub>2</sub> =  $7 \times 20 = 140$  mol (1)

decrease in CO<sub>2</sub> =  $140 \times 24 = 3360$  dm<sup>3</sup> (1) 2

[5]