

The overall equation for aerobic respiration is the same as for the complete combustion of $C_6H_{12}O_6$.

(i) Write the equation for the aerobic respiration of $C_6H_{12}O_6$.



(ii) Explain, in terms of bond breaking and bond forming, why this reaction is exothermic

Bond breaking absorbs energy **AND** bond forming releases energy ✓

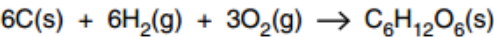
More energy released than absorbed ✓

.....

.....

..... [2]

The enthalpy change of formation, ΔH_f , of glucose, $C_6H_{12}O_6$, cannot be determined directly. The equation for this enthalpy change is shown below.



Suggest why the enthalpy change of formation of $C_6H_{12}O_6$ **cannot** be determined directly.

Would make carbon dioxide and water instead

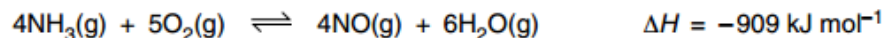
OR activation energy (too) high

OR rate is (too) slow

OR do not react together ✓

..... [1]

An important reaction in the manufacture of nitric acid is the catalytic oxidation of ammonia.



- (a) Low pressures and low temperatures would give the maximum equilibrium yield of NO.

Explain why.

Low pressure because more (gas) molecules on right hand side of equation **OR** low pressure because $\Delta V = \text{positive}$ ✓

Low temperature because the (forward) reaction is exothermic ✓

[2]

- (b) The actual conditions used in the catalytic oxidation of ammonia include 900 °C and an increase in pressure.

Suggest why these conditions are a compromise.

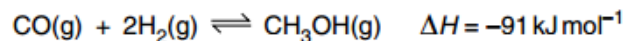
Increased pressure speeds up reaction / or a ✓

900 °C increases the rate **OR** increased temperature speeds up reaction / or a ✓

Idea that high enough temperature without compromising yield **OR** idea that high enough pressure without compromising yield ✓

[3]

In the chemical industry methanol, CH_3OH , is synthesised by reacting together carbon monoxide and hydrogen in the presence of copper, zinc oxide and alumina which act as a catalyst. This is a reversible reaction.



- (a) High pressures and low temperatures would give the maximum equilibrium yield of methanol. Explain why.

high pressure as fewer moles (of gas) on right-hand side of reaction ✓
 high pressure as volume of products less than that of reactants ✓

low temperature as (forward) reaction is exothermic ✓

[2]

- (b) Explain why the actual conditions used in the chemical industry might be different from those in (a) above.

Too expensive to use a high pressure ✓

Too slow to use a low temperature ✓

[2]

(ii) Using the axes below, sketch an enthalpy profile diagram for an exothermic reaction to show how a catalyst provides an alternative reaction route with a lower activation energy. Include on your diagram labels for:

- enthalpy change, ΔH ;
- activation energy for the catalysed route, E_c ;
- activation energy for the uncatalysed route, E_a .

ΔH shown and products below reactants ✓

E_a shown ✓

E_c shown < E_a ✓

