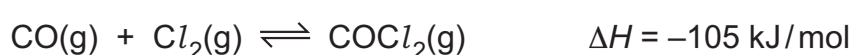


4 Carbonyl chloride, COCl_2 , is manufactured by reacting carbon monoxide with chlorine.



The process takes place in a closed system, and an equilibrium is reached. The conditions for this process are 200°C and 200 kPa .

(a) Explain what is meant by the term closed system.

..... [1]

(b) State what the symbol ΔH represents.

..... [1]

(c) State how the value of ΔH shows that the forward reaction is exothermic.

..... [1]

(d) Deduce the value of ΔH for the reverse reaction. Include a sign in your answer.

..... [1]

(e) Complete Table 4.1 to show the effect, if any, on the concentration of $\text{COCl}_2\text{(g)}$ at equilibrium when the following changes to the conditions are applied.

Use only the words **increases**, **decreases** or **no change**.

Table 4.1

change to conditions	effect on the concentration of $\text{COCl}_2\text{(g)}$ at equilibrium
the temperature is increased	
some CO is added	
the pressure is increased	
a catalyst is added	

[4]

(f) The equation for the reaction can be represented as shown in Fig. 4.1.

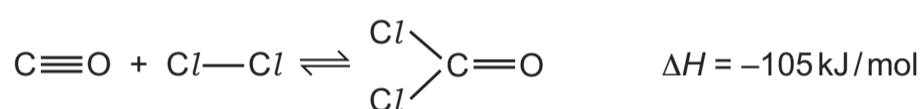


Fig. 4.1

Table 4.2 shows some bond energies.

Table 4.2

bond	$\text{C}\equiv\text{O}$	$\text{Cl}-\text{Cl}$	$\text{C}-\text{Cl}$
bond energy in kJ/mol	1075	240	340

Use the bond energies in Table 4.2 and the value of ΔH for the reaction to calculate the bond energy, in kJ/mol, of the $\text{C}=\text{O}$ bond.

Use the following steps.

- Calculate the energy needed to break the bonds in the reactants.

..... kJ

- Calculate the energy released when the bonds in carbonyl chloride form.

..... kJ

- Calculate the bond energy of the $\text{C}=\text{O}$ bond.

..... kJ/mol
[3]

(g) Complete the dot-and-cross diagram in Fig. 4.2 of a molecule of carbonyl chloride.

Show outer shell electrons only.

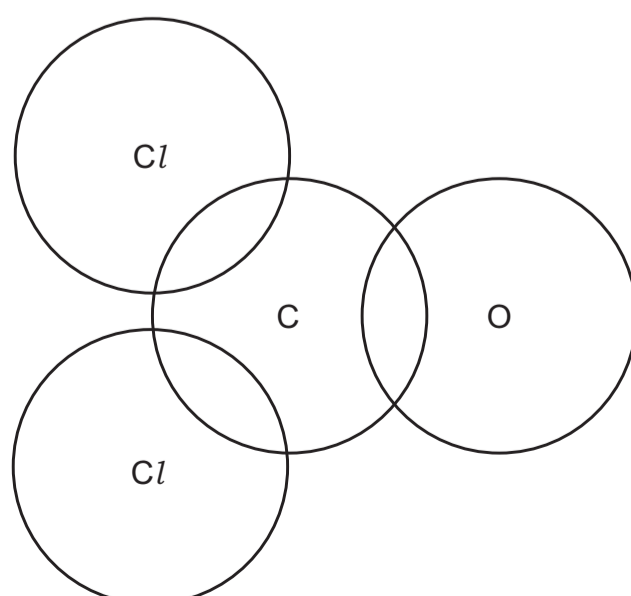


Fig. 4.2

[3]

[Total: 14]