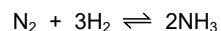


17 Which equation represents one of the reactions in the Contact process?

- A** $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$
B $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{aq})$
C $2\text{SO}_3(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_4(\text{aq})$
D $2\text{SO}_3(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_4(\text{g})$

19 In the Haber process, nitrogen and hydrogen react to form ammonia.



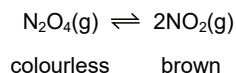
The forward reaction is exothermic.

Which changes in pressure and temperature increase the yield of ammonia?

	change in pressure	change in temperature
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

18 The equation shows the equilibrium between dinitrogen tetroxide, N_2O_4 , and nitrogen dioxide, NO_2 .

The colours of the reactant and product are shown.

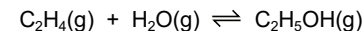


The forward reaction is endothermic.

Which statement is **not** correct?

- A** At equilibrium, the concentrations of the reactant and the product stay constant.
B At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reaction.
C When the pressure is increased, a darker brown colour is seen.
D When the temperature is increased, a darker brown colour is seen.

19 Ethanol is manufactured by the addition of steam to ethene.



The reaction conditions are 300 °C and 60 atm.

The forward reaction is exothermic.

Which rows describe the effect on the equilibrium yield of $\text{C}_2\text{H}_5\text{OH}$ when the stated change is made?

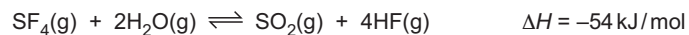
	change	equilibrium yield of $\text{C}_2\text{H}_5\text{OH}$
1	adding a catalyst	no change
2	decreasing the temperature	increases
3	decreasing the pressure	increases

- A** 1 and 2 **B** 1 and 3 **C** 2 only **D** 3 only

20 Which row identifies the conditions used to make sulfur trioxide in the Contact process?

	pressure / kPa	catalyst
A	200	iron
B	200	vanadium(V) oxide
C	20 000	iron
D	20 000	vanadium(V) oxide

4 Gaseous sulfur tetrafluoride, SF₄, reacts with steam in a reversible reaction.



(a) Complete the reaction pathway diagram in Fig. 4.1 for this reaction.

Include in your diagram:

- the position and the formulae of the products
- an arrow, labelled E_a , to show the activation energy
- an arrow, labelled ΔH , to show the enthalpy change of the reaction.

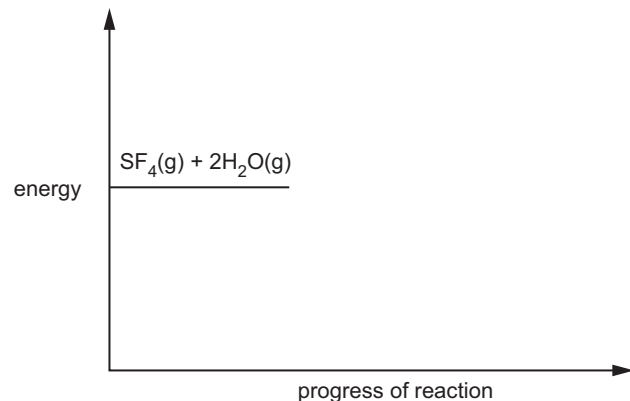


Fig. 4.1

[4]

(b) The equation for the reaction can be represented as shown in Fig. 4.2.

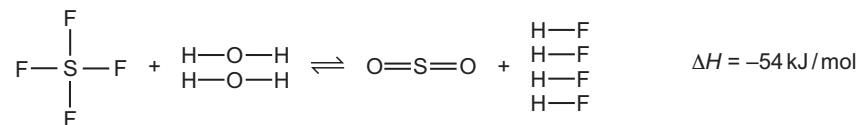


Fig. 4.2

Table 4.1 shows some bond energies.

Table 4.1

bond	S-F	O-H	H-F
bond energy in kJ/mol	330	460	570

Use the bond energies in Table 4.1 and the value of ΔH of the reaction to calculate the S=O bond energy in kJ/mol.

Use the following steps.

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

..... kJ

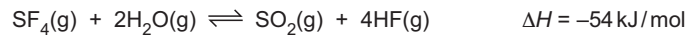
- Calculate the energy released when the bonds in the products form.

..... kJ

- Calculate the S=O bond energy.

..... kJ/mol
[4]

(c) The equation for the reaction is shown.



State the effect, if any, on the position of equilibrium when the following changes are made.

Give a reason for each of your answers.

- The temperature is increased.

.....
.....

- The pressure is increased.

.....
.....

- A catalyst is added.

.....
.....

[5]

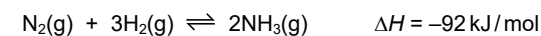
(d) Explain, in terms of collision theory, why reducing the temperature decreases the rate of the reverse reaction.

.....
.....
.....
.....
.....
..... [3]

[Total: 16]

Question 5 starts on the next page.

16 Industrially, ammonia is made by the Haber process. The equation is shown.



The conditions used are 450 °C and 200 atm.

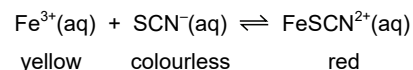
Which statements about the conditions are correct?

- 1 Temperatures below 450 °C give a lower rate of reaction.
- 2 Temperatures below 450 °C give a lower yield of ammonia.
- 3 Pressures above 200 atm give a lower yield of ammonia.
- 4 Pressures above 200 atm are too expensive to maintain.

A 1 and 2 B 1 and 4 C 2 and 3 D 3 and 4

- 16** The reaction between aqueous iron(III) ions, Fe^{3+} , and aqueous thiocyanate ions, SCN^- , is reversible.

The equation for the reaction is shown.



At equilibrium, the concentrations of Fe^{3+} ions, SCN^- ions, and FeSCN^{2+} ions are identical, and the mixture appears orange.

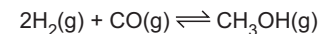
When a few drops of aqueous thiocyanate ions are added to the mixture, a new equilibrium forms.

How does the colour of the mixture change?

- A** It becomes colourless.
- B** It becomes a lighter orange.
- C** It becomes more yellow.
- D** It becomes more red.

- 5** Methanol, CH_3OH , is manufactured by the reaction between hydrogen and carbon monoxide.

An equilibrium mixture is produced.



- (a)** State what happens to the concentration of CH_3OH when the reaction is at equilibrium.

Explain your answer in terms of rate of forward and reverse reactions.

.....

.....

..... [2]

- (b)** The reaction is carried out at a pressure of 75 atmospheres and a temperature of 250°C .

- (i)** State **two** disadvantages of using a pressure **below** 75 atmospheres.

1

2 [2]

- (ii)** Complete Table 5.1 using **only** the words **increases**, **decreases** or **no change**.

Table 5.1

	effect on the concentration of $\text{CH}_3\text{OH}(\text{g})$ at equilibrium	effect on the rate of the reverse reaction
catalyst is added		

[2]

- (iii)** If a temperature of more than 250°C is used, the yield of methanol decreases.

State what can be deduced about the forward reaction.

..... [1]

- (iv)** Suggest which of the elements from the list is a suitable catalyst for the reaction. Give a reason for your answer.

barium carbon copper potassium sulfur

catalyst

reason

[2]

(c) Methanol is a member of the homologous series of alcohols.

(i) State **two** characteristics of all members of a homologous series.

1

2

[2]

(ii) State the molecular formula of an alcohol that contains five carbon atoms.

..... [1]

(d) Carboxylic acids react with alcohols to form esters.

(i) Draw the displayed formula of an ester which contains three carbon atoms.

[2]

(ii) Butyl ethanoate is an ester.

Name the alcohol and the carboxylic acid that react to produce butyl ethanoate.

alcohol

carboxylic acid

[2]

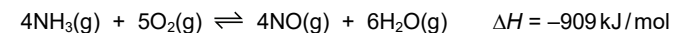
(e) An organic compound has the following composition by mass:

C, 64.87%; H, 13.51%; O, 21.62%.

Calculate the empirical formula of the compound.

empirical formula = [2]

20 The equation for the reaction between ammonia and oxygen is shown.



Which two changes to the reaction conditions will **both** move the position of equilibrium to the right?

	change 1	change 2
A	increasing the temperature	decreasing the pressure
B	increasing the temperature	increasing the pressure
C	decreasing the temperature	increasing the pressure
D	decreasing the temperature	decreasing the pressure