Past-paper walk-through

Reversible reactions and equilibrium ▪ 6.3

eXercise

Questions in this set

- 0620/21 N25 Q17 ▪ 1 mark
- 0620/21 N25 Q19 ▪ 1 mark
- 0620/22 N25 Q18 ▪ 1 mark
- 0620/23 N25 Q19 ▪ 1 mark
- 0620/23 N25 Q20 ▪ 1 mark
- 0620/41 N25 Q4 ▪ 16 marks
- 0620/21 J25 Q16 ▪ 1 mark
- 0620/23 J25 Q16 ▪ 1 mark
- 0620/41 J25 Q5 ▪ 18 marks
- 0620/22 M25 Q20 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 17

0620/21 N25 ▪ Q17 ▪ 1 mark

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

A $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

B $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(aq)$

C $2SO_3(g) + O_2(g) \rightleftharpoons 2SO_4(aq)$

D $2SO_3(g) + O_2(g) \rightleftharpoons 2SO_4(g)$

Solution 17

Answer: **A**

Why

- The Contact process makes sulfur trioxide from sulfur dioxide and oxygen.
- All three species are gases in the converter, so all are labelled (g).
- $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ – and SO_4 does not exist as a molecule.

Question 19

0620/21 N25 ▪ Q19 ▪ 1 mark

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

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

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

Question 19

C	increase	decrease
D	increase	increase

Solution 19

Answer: **C**

Why

- There are 4 moles of gas on the left and 2 on the right, so high pressure favours ammonia.
- The forward reaction is exothermic, so a *low* temperature favours ammonia.
- So increasing the pressure and decreasing the temperature both raise the yield.

Question 18

0620/22 N25 ▪ Q18 ▪ 1 mark

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.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

colourless brown

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.

Question 18

C When the pressure is increased, a darker brown colour is seen.

D When the temperature is increased, a darker brown colour is seen.

Solution 18

Answer: **C**

Why

- The forward reaction is endothermic, so *raising* the temperature shifts it to the right.
- More NO_2 means the mixture turns browner.
- Raising the pressure would shift it left, since there are fewer gas moles on that side, turning it paler.

Question 19

0620/23 N25 ▪ Q19 ▪ 1 mark

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

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

The reaction conditions are 300 °C and 60 atm.

The forward reaction is exothermic.

Which rows describe the effect on the equilibrium yield of C_2H_5OH when the stated change is made?

	change	equilibrium yield of C_2H_5OH
1	adding a catalyst	no change
2	decreasing the temperature	increases

Question 19

3	decreasing the pressure	increases

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

Solution 19

Answer: **A**

Why

- There are 2 moles of gas on the left and 1 on the right, so high pressure favours the ethanol.
- The forward reaction is exothermic, so a *low* temperature favours the ethanol.
- So raising the pressure and lowering the temperature both increase the equilibrium yield.

Question 20

0620/23 N25 ▪ Q20 ▪ 1 mark

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

Solution 20

Answer: **B**

Why

- The Contact process uses a vanadium(V) oxide catalyst – iron belongs to the Haber process.
- The pressure used is only slightly above atmospheric, about 200 kPa.
- A very high pressure is unnecessary here and would add cost for little gain.

Question 4

0620/41 N25 ▪ Q4 ▪ 16 marks

4 Gaseous sulfur tetrafluoride, SF_4, reacts with steam in a reversible reaction.

$$SF_4(g) + 2H_2O(g) \rightleftharpoons SO_2(g) + 4HF(g) \qquad \Delta H = -54\,kJ/mol$$

(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.

Question 4

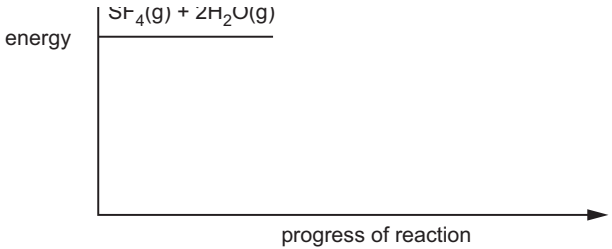

Fig. 4.1

[4]

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

Question 4

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.

Question 4

..... kJ

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

..... kJ

Question 4

Question 4

- Calculate the S=O bond energy.

Question 4

[4]

(c) The equation for the reaction is shown.

$$SF_4(g) + 2H_2O(g) \rightleftharpoons SO_2(g) + 4HF(g) \qquad \Delta H = -54\,kJ/mol$$

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.

Question 4

- The pressure is increased.

Question 4

- A catalyst is added.

Question 4

[5]

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

Question 4

[Total: 16]

Question 4

Question 4

Question 5 starts on the next page.

Solution 4

(a) Mark scheme

- M1 energy level of products below energy level of reactants **M2**
- label of SO2(g) + 4HF(g) on product line **M3**
- upward arrow labelled Ea from energy level of reactants to the highest point of the curve **M4**
- one downward arrow labelled ΔH
- AND
- energy change starting from energy level of reactants and finishing at energy level of products
- 4

Solution 4

(b)

Mark scheme

- M1 = $(4 \times \text{S–F}) + (4 \times \text{O–H}) = (4 \times 330) + (4 \times 460) = 3160$ M2
- bond energy of products – 3160 = –54
- = 3160 – (–54) = 3214 M3
- $(2 \times \text{S=O}) + (4 \times \text{H–F}) = 3214$ therefore $2 \times \text{S=O} = 3214 - (4 \times 570) = 934$ M4
- S=O = M3 ÷ 2 = 934 ÷ 2 = 467
- 4

Solution 4

(c) Mark scheme

- increased temperature: M1
- (position of) equilibrium moves to left hand side M2
- reaction is exothermic
- increased pressure: M3
- (position of) equilibrium moves to left hand side M4
- less (gaseous) moles on left hand side M5
- no change / catalyst does not affect position of equilibrium
- 5

Solution 4

(d) Mark scheme

- M1 kinetic energy of particles decreases **M2**
- frequency of collisions between particles decreases **M3**
- lower percentage/proportion/fraction of collisions / particles have energy greater than / equal to activation energy
- 3
- 0620/41
- October/November 2025

Question 16

0620/21 J25 ▪ Q16 ▪ 1 mark

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

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,\text{kJ/mol}$$

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.

Question 16

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

Solution 16

Answer: **B**

Why

- The forward reaction is exothermic, so a low temperature would give the best yield – but far too slowly.
- $450\,^{\circ}\mathrm{C}$ is a compromise between yield and rate.
- High pressure genuinely favours the forward reaction, since there are fewer moles of gas on the right.

Question 16

0620/23 J25 ▪ Q16 ▪ 1 mark

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

The equation for the reaction is shown.

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

yellow colourless red

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?

Question 16

A It becomes colourless.

B It becomes a lighter orange.

C It becomes more yellow.

D It becomes more red.

Solution 16

Answer: **D**

Why

- The mixture's colour tells you which species dominates at equilibrium.
- Adding more of a reactant shifts the position to the right, deepening the red.
- Removing a reactant shifts it left, so the red fades towards yellow.

Question 5

0620/41 J25 ▪ Q5 ▪ 18 marks

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

An equilibrium mixture is produced.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

(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.

Question 5

(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.

Question 5

Question 5

[2]

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

Table 5.1

	effect on the concentration of $CH_3OH(g)$ 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.

Question 5

(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**

Question 5

Question 5

[2]

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

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

Question 5

Question 5

[2]

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

Question 5

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

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

Question 5

[2]

(ii) Butyl ethanoate is an ester.

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

Question 5

[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.

Question 5

Question 5

Question 5

[Total: 18]

Solution 5

(a)

Mark scheme

- M1 concentration is no longer changing M2
- rates of forward reaction and of the reverse reaction are equal
- 2

Solution 5

(b)(i)

Mark scheme

- M1 rate decreases M2
- yield of methanol decreases
- 2

Solution 5

(b)(ii)

Mark scheme

- no change(1) increases [1]
- 2

(b)(iii)

Mark scheme

- exothermic
- 1

Solution 5

(b)(iv)

Mark scheme

- M1 copper M2
- transition element
- 2

Solution 5

(c)(i) Mark scheme

- any 2 from:
- ▪
- same or similar chemical properties or reactions
- ▪
- (same) general formula
- ▪
- (consecutive members) differ by CH2
- ▪

Solution 5

- same functional group
- ▪
- physical properties OR
- example of a physical property
- e.g. melting point /
- boiling point /
- volatility
- vary in predictable manner or show trends or gradually change
- 2

Solution 5

(c)(ii)

Mark scheme

- C5H12O
- 1
- 0620/41
- May/June 2025

Solution 5

(d)(i)

Mark scheme

- M1 displayed formula of ester linkage, i.e.
- H or C M2
- completely correct displayed formula of methyl ethanoate or ethyl methanoate
- i.e.
- 2

Solution 5

(d)(ii)

Mark scheme

- M1 butan-1-ol M2
- ethanoic acid
- 2
- 0620/41
- May/June 2025

Solution 5

(e) Mark scheme

- M1 C 64.87 / 12
- H 13.51 / 1
- O 21.62 / 16
- OR
- 5.41 13.51 1.35 **M2**
- C4H10O
- 2

Question 20

0620/22 M25 ▪ Q20 ▪ 1 mark

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

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -909\,kJ/mol$$

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

Solution 20

Answer: **D**

Why

- The forward reaction is exothermic, so *lowering* the temperature shifts it right.
- There are 9 moles of gas on the left and 10 on the right, so going forwards increases the volume.
- *Lowering* the pressure therefore also shifts it right.