1 Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
An equilibrium forms between these iodine chlorides.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

(a) What do you understand by the term *equilibrium*?

.....

.....

..... [2]

(b) When the equilibrium mixture is heated, it becomes a darker brown colour.
Suggest if the reverse reaction is endothermic or exothermic. Give a reason for your choice.

.....

.....

..... [1]

(c) The pressure on the equilibrium mixture is decreased.

(i) How would this affect the position of equilibrium? Give a reason for your choice.

It would move to the .....

reason .....

..... [1]

(ii) Describe what you would observe.

.....

..... [1]

(d) Calculate the overall energy change for the reaction between iodine and chlorine using the bond energy values shown.

$$I_2 + Cl_2 \rightarrow 2ICl$$

Bond	Energy / kJ per mol
I–I	151
Cl–Cl	242
I–Cl	208

Show your working.

[3]

(e) Draw a labelled energy level diagram for the reaction between iodine and chlorine using the information in **(d)**.

[2]

[Total: 10]

2 Reversible reactions can come to equilibrium. The following are three examples of types of gaseous equilibria.

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$ **reaction 1**

$A_2(g) + 3B_2(g) \rightleftharpoons 2AB_3(g)$ **reaction 2**

$2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$ **reaction 3**

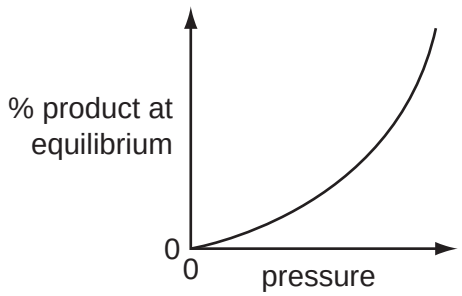
(a) Explain the term *equilibrium*.

.....

..... [2]

(b) The following graphs show how the percentage of products of a reversible reaction at equilibrium could vary with pressure.
For each graph, decide whether the percentage of products decreases, increases or stays the same when the pressure is **increased**, then match each graph to one of the above reactions and give a reason for your choice.

(i)



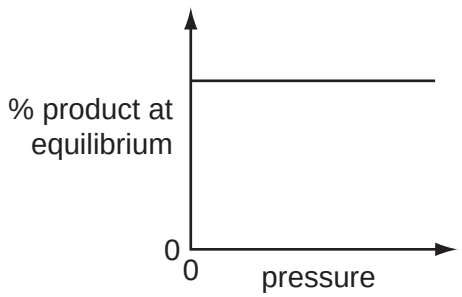
effect on percentage of products .....

reaction .....

reason .....

..... [3]

(ii)



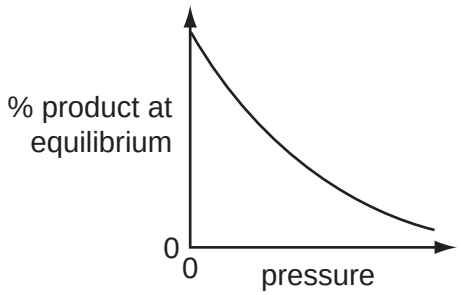
effect on percentage of products .....

reaction .....

reason .....

..... [3]

(iii)



effect on percentage of products .....

reaction .....

reason .....

..... [3]

[Total: 11]

3 Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
There is an equilibrium between these iodine chlorides.

$$ICl(l) + Cl_2(g) \rightleftharpoons ICl_3(s)$$
dark brown yellow

(a) Explain what is meant by *equilibrium*.

.....

.....

..... [2]

(b) When the equilibrium mixture is heated it becomes a darker brown colour.
Is the reverse reaction endothermic or exothermic? Give a reason for your choice.

.....

.....

..... [2]

(c) The pressure on the equilibrium mixture is decreased.

(i) How would this affect the position of equilibrium and why?

It would move to the ..... [1]

reason .....

..... [1]

(ii) Describe what you would observe.

.....

..... [1]

[Total: 7]

4 Nitrogen dioxide is a brown gas. It can be made by heating certain metal nitrates.

$$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$$

(a) Name another metal whose nitrate decomposes to give the metal oxide, nitrogen dioxide and oxygen.

..... [1]

(ii) Complete the word equation for a metal whose nitrate does not give nitrogen dioxide on decomposition.

metal nitrate $\rightarrow$ ..... + oxygen

[1]

(b) At most temperatures, samples of nitrogen dioxide are equilibrium mixtures.

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

dark brown pale yellow

(i) At 25 °C, the mixture contains 20 % of nitrogen dioxide. At 100 °C this has risen to 90 %. Is the forward reaction exothermic or endothermic?
Give a reason for your choice.

.....

.....

..... [2]

(ii) Explain why the colour of the equilibrium mixture becomes lighter when the pressure on the mixture is increased.

.....

.....

..... [2]

(c) A 5.00 g sample of impure lead(II) nitrate was heated. The volume of oxygen formed was 0.16 dm^3 measured at r.t.p. The impurities did not decompose.
Calculate the percentage of lead(II) nitrate in the sample.

$$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$$

Number of moles of O_2 formed = ...

Number of moles of $Pb(NO_3)_2$ in the sample = ...

Mass of one mole of $Pb(NO_3)_2$ = 331 g

Mass of lead(II) nitrate in the sample = ... g

Percentage of lead(II) nitrate in sample = ... [4]

[Total: 10]

5 Carbonyl chloride, $COCl_2$, is a colourless gas. It is made by the following reaction.

$$CO(g) + Cl_2(g) \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} COCl_2(g)$$

(a) When the pressure on the equilibrium mixture is decreased, the position of equilibrium moves to left.

(i) How does the concentration of each of the three chemicals change?

.....

..... [2]

(ii) Explain why the position of equilibrium moves to left.

.....

..... [2]

(b) Using the information given with the equation, is the forward reaction exothermic or endothermic? Give a reason for your choice.

.....

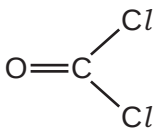
..... [2]

(c) Carbonyl chloride reacts with water to form two acidic compounds.
Suggest which acidic compounds are formed.

1. .....

2. ..... [2]

(d) The structural formula of carbonyl chloride is given below.



Draw a diagram that shows the arrangement of the valency electrons in one molecule of this covalent compound.
Use x for an electron from a chlorine atom.
Use o for an electron from a carbon atom.
Use ● for an electron from an oxygen atom.

[4]
[Total: 12]

6 Reversible reactions can come to equilibrium. They have both a forward and a backward reaction.

(a) When water is added to an acidic solution of bismuth(III) chloride, a white precipitate forms and the mixture slowly goes cloudy.

$$\underset{\text{colourless}}{BiCl_3(aq)} + H_2O(l) \underset{\text{backward}}{\overset{\text{forward}}{\rightleftharpoons}} \underset{\text{white}}{BiOCl(s)} + 2HCl(aq)$$

(i) Explain why the rate of the forward reaction decreases with time.

.....

..... [2]

(ii) Why does the rate of the backward reaction increase with time?

.....

..... [1]

(iii) After some time why does the appearance of the mixture remain unchanged?

.....

..... [2]

(iv) When a few drops of concentrated hydrochloric acid are added to the cloudy mixture, it changes to a colourless solution. Suggest an explanation.

.....

..... [2]

(b) Both of the following reactions are reversible.

reaction 1 $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

reaction 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

(i) Suggest a reason why an increase in pressure does not affect the position of equilibrium for reaction 1.

.....

..... [1]

(ii) What effect would an increase in pressure have on the position of equilibrium for reaction 2? Give a reason for your answer.

.....

.....

.....

..... [2]

7 The simplest alcohol is methanol.

(a) It is manufactured by the following reversible reaction.

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g)$$
$$300\,^{o}C$$
$$30atm$$

(i) Reversible reactions can come to equilibrium. Explain the term *equilibrium*.

.....

[1]

(ii) At 400 °C, the percentage of methanol in the equilibrium mixture is lower than at 300 °C. Suggest an explanation.

.....

[2]

(iii) Suggest two advantages of using high pressure for this reaction.
Give a reason for each advantage.

advantage	.....
reason	.....

advantage	.....
reason	.....
	[5]

(b) **(** Complete the equation for the combustion of methanol in an excess of oxygen.

$$\square\ CH_3OH + \square\ O_2 \longrightarrow \square + \square$$

[2]

(ii) Complete the word equation.

methanol + ethanoic acid ⟶ ..... + ...

[2]

(iii) Methanol can be oxidised to an acid. Name this acid.

.....

[1]