Answer **all** the questions.

Use

1 When heated, chlorine gas, Cl_2 dissociates into gaseous chlorine atoms.

$$Cl_2(g) \rightleftharpoons 2Cl(g)$$

A chemist placed some chlorine gas in a container which was heated to 1400 K. The container was left until equilibrium had been reached.

Under these conditions, the equilibrium partial pressure of $Cl_2(g)$ is 85.0 kPa and that of $Cl(g)$ is 3.0 kPa.

(a) What is meant by *partial pressure*?

.....

.....[1]

(b) Determine the mole fraction of Cl in the equilibrium mixture.

[1]

(c) **(i)** Write an expression for K_p for this equilibrium.

[1]

(ii) Calculate K_p for this equilibrium. State the units.

answer ..... units ..... [2]

(d) The chemist compressed the reaction mixture and allowed it to reach equilibrium under these new conditions.

Explain what happened to the composition of the equilibrium mixture.

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.....[2]

(e) The chemist changed the temperature of the reaction mixture. The value of K_p decreased.

Explain how this change affected the composition of the equilibrium mixture.

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.....[1]

(f) Industrially, chlorine is prepared by passing an electric current through a 4.00 mol dm^{-3} solution of sodium chloride, known as brine.

$$2NaCl(aq) + 2H_2O(l) \rightarrow Cl_2(g) + 2NaOH(aq) + H_2(g)$$

Each year in the UK, 1.6 million tonnes of Cl_2 is produced for many uses, including water treatment and the manufacture of plastics.

Calculate the volume of brine required each year for Cl_2 production in the UK.

1 tonne = 10^6 g.

Examiner's Use

Nitrogen dioxide is one of the major pollutants in air, formed by reaction of nitrogen monoxide with oxygen.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

(a) What is meant by the *rate of reaction*?

.....

.....[1]

(b) A series of experiments was carried out to investigate the kinetics of this reaction. The results are shown in the table below.

Experiment	$[O_2]$ / mol dm^{-3}	[NO] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.00100	0.00100	7.10
2	0.00400	0.00100	28.4
3	0.00400	0.00300	256

(i) For each reactant, deduce the order of reaction. Show your reasoning.

$O_2(g)$ .....

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NO(g) .....

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.....[4]

(ii) Deduce the rate equation for this reaction.

.....[1]

(iii) Calculate the rate constant, k, for this reaction. State the units for k.

k = units .....[2]

(c) Nitrogen dioxide reacts with carbon monoxide emitted from car exhausts in the following reaction.

$$NO_2 + CO \longrightarrow NO + CO_2$$

The rate equation for this reaction is $rate = k[NO_2]^2$.

This is a multi-step reaction. The first step is the rate-determining step.

(i) What is meant by the *rate-determining step*?

.....

.....[1]

(ii) Suggest a two-step reaction mechanism for this reaction that is consistent with the kinetic data and the overall reaction.

[2]

(d) NO_2 reacts with oxygen and water to form nitric acid, HNO_3. In the atmosphere, this contributes to acid rain. Construct a balanced equation for this formation of nitric acid and use oxidation numbers to show that this is a redox reaction.

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.....[2]

[Total: 13]

For Examiner's Use

3 The K_a values for three acids are shown in the table below.

acid		K_a / mol dm^{-3}
ethanoic acid	CH_3COOH	1.70×10^{-5}
phenol	C_6H_5OH	1.28×10^{-10}
sulphurous acid	H_2SO_3	1.50×10^{-2}

(a) What information is provided by K_a values?

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.....[1]

(b) When sulphurous acid and ethanoic acid are mixed together, an acid-base reaction takes place.

$$H_2SO_3(aq) + CH_3COOH(aq) \rightleftharpoons HSO_3^-(aq) + CH_3COOH_2^+(aq)$$

....

(i) In the spaces above

- label one **conjugate acid-base pair** as acid 1 and base 1,
- label the other **conjugate acid-base pair** as acid 2 and base 2.

[2]

(ii) Predict and explain the acid-base reaction that would take place if ethanoic acid were mixed with phenol. Include an equation in your answer.

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.....[2]

(c) The pH value of 0.0450 mol dm^{-3} hydrochloric acid is different from that of 0.0450 mol dm^{-3} ethanoic acid.

Calculate the pH values of these two acids. Show all your working.

[5]

(d) An excess of magnesium was added to 100 cm^3 of 0.0450 mol dm^{-3} hydrochloric acid. The same mass of magnesium was added to 100 cm^3 of 0.0450 mol dm^{-3} ethanoic acid.

Both reactions produced 54 cm^3 of hydrogen gas, measured at room temperature and pressure, but the reaction with ethanoic acid took much longer to produce this gas volume.

Explain why the reactions produced the same volume of a gas but at different rates.

Use equations in your answer.

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.....[4]

[Total: 14]

For Examiner's Use

4 In this question, one mark is available for the quality of use and organisation of scientific terms.

Mixtures of ammonia, NH_3, and ammonium chloride, NH_4Cl, can be used as the basis of buffer solutions.

Explain how this mixture acts as a buffer solution.

Use equations in your answer.

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.....[6]

Quality of Written Communication [1]

[Total: 7]

5 This question looks at some chemicals found in food.

1 mole of gas molecules occupies 24.0 dm^3 at room temperature and pressure.

The Avogadro constant = $6.02 \times 10^{23}\ mol^{-1}$.

(a) A chemistry student bought a bar of chocolate. The student looked on the label and found that the main ingredient listed was 'sugars', making up 47.0% by mass of the 43.0 g chocolate bar. Throughout this question you can assume that all the sugars are present as sucrose, $C_{12}H_{22}O_{11}$.

(i) How many sucrose molecules were in the bar of chocolate?

[4]

(ii) The student ate the bar of chocolate. The standard enthalpy change of combustion of sucrose is $-5640\ kJ\ mol^{-1}$. On food labels, the energy content is measured in Calories. 1 Calorie = 4.18 kJ.

- Write an equation for the chemical change involved in the standard enthalpy change of combustion of sucrose.
- How much energy, in Calories, is available to the student from the sugars in the chocolate bar?

energy = ... Calories [3]

(b) An oxide of nitrogen is used as the propellant in whipped cream. This oxide contains 63.64% N by mass, and has a density of $1.833\ g\ dm^{-3}$ at room temperature and pressure.

[illegible] Show your working

(c) Chocolate mousse contains gelatine and a compound to promote fast setting of the mousse.

Compound **A** is such a setting agent. It has two acidic hydrogen atoms per molecule and is one of the six acids listed below.

oxalic acid	HOOCCOOH
malonic acid	$HOOCCH_2COOH$
succinic acid	$HOOC(CH_2)_2COOH$
glutaric acid	$HOOC(CH_2)_3COOH$
adipic acid	$HOOC(CH_2)_4COOH$
pimelic acid	$HOOC(CH_2)_5COOH$

The student analysed a sample of compound **A** by titration.

The student dissolved 2.82 g of compound **A** in water and made the solution up to 250 cm^3 in a volumetric flask. He titrated 25.0 cm^3 of this solution with 0.175 mol dm^{-3} NaOH.

22.05 cm^3 of NaOH were required for complete neutralisation.

Use the results of the student's analysis to identify compound **A** from the list above.

Show all of your working.

[5]

[Total: 15]

END OF QUESTION PAPER