Chemistry

Higher Level

Paper 2 — Mock Examination

Mock Exam 2

Calculator required

Time allowed: **2 hours 30 minutes**

Maximum mark: **90 marks**

Candidate information

Candidate name: .....

Session number: .....

Date: .....

Topic emphasis: models of bonding and structure, classification of matter, periodicity, what drives chemical reactions, how much / how fast / how far, what are the consequences of electron transfer, and the mechanisms of chemical change.

Instructions to candidates

- Write your session number in the box on the cover.
- Do not open this examination paper until you are told to do so.
- Answer **all** questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

The mark allocation is shown in square brackets at the end of each question or part question. Where a numerical answer is required, values of constants, molar masses and other data should be taken from the chemistry data booklet unless they are given in the question. Working must be shown for all calculations; marks are available for correct method even when the final answer is incorrect.

Take the ideal gas constant to be $R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$, Avogadro's constant to be $L = 6.02 \times 10^{23}\,\text{mol}^{-1}$ and the specific heat capacity of water to be $4.18\,\text{J}\,\text{g}^{-1}\,\text{K}^{-1}$. All questions refer to a temperature of 298 K unless otherwise stated.

Mark allocation	
Question 1	[20 marks]
Question 2	[16 marks]
Question 3	[24 marks]
Question 4	[16 marks]
Question 5	[14 marks]
Total	**[90 marks]**

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Ammonia, NH_3, is manufactured by the Haber process and is the starting material for the production of nitric acid and fertilizers.

(a) Draw the Lewis formula of ammonia, state its molecular geometry and explain why its bond angle is smaller than that in methane. **[3]**

Molecular geometry: .....

Explanation: .....

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(b) Explain why ammonia has a much higher boiling point than phosphine, PH_3. **[2]**

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(c) State the formula of the conjugate acid of ammonia. **[1]**

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(This question continues on the following page)

(Question 1 continued)

(d) Ammonia is produced in a reversible reaction.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) \qquad \Delta H^{\ominus} = -92.2\,\text{kJ mol}^{-1}$$

(i) Deduce the equilibrium constant expression, K_c, for this reaction. **[1]**

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(ii) 1.00 mol of nitrogen and 3.00 mol of hydrogen were placed in a 2.00 dm^3 container and allowed to reach equilibrium. The equilibrium mixture contained 0.60 mol of ammonia. Calculate the value of K_c. **[3]**

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(iii) State and explain the effect of increasing the temperature on the value of K_c and on the equilibrium yield of ammonia. **[2]**

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(iv) Suggest, with a reason, the effect of increasing the pressure on the equilibrium yield of ammonia. **[1]**

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(This question continues on the following page)

(Question 1 continued)

(e) The entropy change of the Haber process is $-198\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$.

(i) Outline why the entropy change is negative. **[1]**

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(ii) Determine the temperature, in K, above which the forward reaction is no longer spontaneous. Use section 1 of the data booklet. **[2]**

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(f) Ammonia acts as a weak base in aqueous solution. $K_b(\text{NH}_3) = 1.8 \times 10^{-5}$ at 298 K.

(i) Write an equation for the reaction of ammonia with water. **[1]**

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(ii) Calculate the pH of $0.100\,\text{mol}\,\text{dm}^{-3}$ aqueous ammonia. Use section 1 of the data booklet. **[2]**

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(g) In the Ostwald process, ammonia is oxidized to nitrogen monoxide. Deduce the oxidation state of nitrogen in NH_3 and in NO. **[1]**

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2. The halogens show clear trends in their physical and chemical properties.

(a) Explain why the melting points of the halogens increase down group 17. **[2]**

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(b) Aqueous chlorine was added to separate samples of potassium bromide solution and potassium iodide solution. Aqueous iodine was then added to a further sample of potassium bromide solution. Predict the observations and support your answer with an equation and with electrode potential data. Use section 19 of the data booklet. **[3]**

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(c) Chlorine reacts with cold dilute sodium hydroxide.

$$Cl_2(aq) + 2\,NaOH(aq) \longrightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$$

Deduce the oxidation states of chlorine in the products and explain why this is described as a disproportionation reaction. **[2]**

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(This question continues on the following page)

(Question 2 continued)

(d) The concentration of an iodine solution was determined by titration with sodium thiosulfate.

$$I_2(aq) + 2\,S_2O_3{}^{2-}(aq) \longrightarrow 2\,I^-(aq) + S_4O_6{}^{2-}(aq)$$

A 25.0 cm^3 portion of the iodine solution required 22.4 cm^3 of 0.0500 $mol\,dm^{-3}$ sodium thiosulfate solution to reach the end point.

(i) Calculate the concentration of the iodine solution, in $mol\,dm^{-3}$. **[2]**

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(ii) State the indicator used and the colour change at the end point. **[1]**

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(e) Explain why hydrogen fluoride has a higher boiling point than hydrogen chloride, even though hydrogen chloride has the greater molar mass. **[2]**

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(f) Concentrated aqueous sodium chloride is electrolysed.

(i) Deduce the half-equation for the reaction at each electrode. **[2]**

Anode: . . . . . .

Cathode: . . . . . .

(ii) State one observation at the cathode. **[1]**

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(g) Outline one benefit and one risk of using chlorine to treat drinking water. **[1]**

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3. Ethene is converted industrially into a range of oxygen-containing compounds.

(a) Ethene undergoes catalytic hydration.

(i) Write an equation for the reaction and state the type of reaction. **[2]**

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(ii) State one advantage of producing ethanol by this route rather than by fermentation. **[1]**

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(b) Ethanol is oxidized by acidified potassium dichromate(VI).

(i) State the organic product obtained under distillation and the organic product obtained under reflux. **[2]**

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(ii) Write an equation for the complete oxidation of ethanol, using [O] to represent the oxidizing agent. **[1]**

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(This question continues on the following page)

(Question 3 continued)

(c) Ethanoic acid is a weak acid.

(i) Deduce the expression for K_a of ethanoic acid. **[1]**

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(ii) Chloroethanoic acid, $ClCH_2COOH$, has a pK_a of 2.87 whereas ethanoic acid has a pK_a of 4.76. Suggest an explanation for this difference. **[2]**

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(d) Ethanoic acid reacts with methanol in the presence of a small amount of concentrated sulfuric acid.

(i) Write an equation for the reaction and name the organic product. **[2]**

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(ii) State the role of the concentrated sulfuric acid. **[1]**

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(e) Hexanedioic acid, $HOOC(CH_2)_4COOH$, reacts with 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$.

(i) State the type of polymerization and the name of the linkage formed. **[1]**

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(ii) Draw one repeating unit of the polymer. **[2]**

(This question continues on the following page)

(Question 3 continued)

(f) 1-chlorobutane and 2-chloro-2-methylpropane were each warmed with aqueous sodium hydroxide.

(i) Sketch the mechanism of the reaction of 2-chloro-2-methylpropane, using curly arrows to represent the movement of electron pairs. **[3]**

(ii) Explain why a tertiary halogenoalkane reacts by this mechanism whereas a primary halogenoalkane does not. **[1]**

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(This question continues on the following page)

(Question 3 continued)

(g) Ethyl ethanoate, $CH_3COOCH_2CH_3$, was analysed by ^1H NMR spectroscopy. Deduce the number of signals and the splitting pattern of each signal. Use section 21 of the data booklet. **[2]**

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(h) Methane reacts with chlorine in the presence of ultraviolet light. Name the three stages of the mechanism and write an equation for each stage. **[3]**

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4. Thermochemical data allow the enthalpy and Gibbs energy changes of reactions to be determined without carrying out the reaction.

(a) The standard enthalpies of combustion of carbon, hydrogen and methane are $-394\,\text{kJ mol}^{-1}$, $-286\,\text{kJ mol}^{-1}$ and $-891\,\text{kJ mol}^{-1}$ respectively. Determine the standard enthalpy of formation of methane, in kJ mol^{-1}. **[3]**

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(b) The value obtained from average bond enthalpies for the same reaction differs from the value calculated in (a). Suggest **two** reasons for this difference. **[2]**

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(c) Predict, with a reason, the sign of the entropy change for the reaction below.

$$2\,H_2O_2(l) \longrightarrow 2\,H_2O(l) + O_2(g)$$

[2]

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(This question continues on the following page)

(Question 4 continued)

(d) Calcium carbonate decomposes on strong heating.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta H^{\ominus} = +178\,\text{kJ mol}^{-1}$$

The standard entropies, in $\text{J K}^{-1}\,\text{mol}^{-1}$, are: $CaCO_3(s)$ 92.9, $CaO(s)$ 39.7, $CO_2(g)$ 213.8.

(i) Calculate the standard entropy change of the reaction. **[1]**

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(ii) Determine the standard Gibbs energy change at 298 K and state whether the reaction is spontaneous at this temperature. Use section 1 of the data booklet. **[2]**

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(iii) Determine the minimum temperature, in K, at which the decomposition becomes spontaneous. **[1]**

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(e) A student burned 0.850 g of ethanol and used the heat released to raise the temperature of 200.0 g of water by 25.0 °C.

(i) Determine the enthalpy of combustion of ethanol, in kJ mol^{-1}, from these results. Use sections 1 and 2 of the data booklet. **[3]**

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(ii) The data booklet value is $-1367\,\text{kJ}\,\text{mol}^{-1}$. Explain **two** reasons for the difference between the experimental and literature values. **[2]**

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5. Copper and its compounds show behaviour typical of the transition elements.

(a) State the condensed electron configuration of a copper atom and of the Cu^{2+} ion. **[2]**

Cu: .....

Cu^{2+}: .....

(b) Explain, in terms of d orbitals, why aqueous solutions containing $[Cu(H_2O)_6]^{2+}$ are coloured.**[2]**

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(c) When concentrated aqueous ammonia is added to a solution containing $[Cu(H_2O)_6]^{2+}$, the pale blue colour changes to deep blue. Explain this observation. **[2]**

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(This question continues on the following page)

(Question 5 continued)

(d) The $[Cu(H_2O)_6]^{2+}$ ion absorbs light of wavelength 8.00×10^{-7} m. Calculate the energy difference between the split d orbitals, in J. Use sections 1 and 2 of the data booklet. **[2]**

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(e) Distinguish between homogeneous and heterogeneous catalysis, giving one example of each.**[2]**

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(f) State the shape of the $[Cu(H_2O)_6]^{2+}$ ion. **[1]**

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(g) Explain why aqueous solutions of Zn^{2+} are colourless. **[1]**

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(h) Deduce the number of unpaired electrons in a Fe^{3+} ion and state what this suggests about the magnetic behaviour of iron(III) compounds. **[2]**

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End of examination.

Total: 90 marks