# AQA A-Level Chemistry: Practice Paper 1

**Focus:** Physical

**Difficulty:** Hard

**Time**: 2 hours

**Marks:**

Section A (multiple choice): 15 marks (30 minutes)

Section B (standard questions): 75 marks (1 hour 30 minutes)

(Total 90 marks)

**Grade Boundaries:** (approximate)

A*: 72 (80%)

A: 63 (70%)

B: 54 (60%)

C: 45 (50%)

D: 36 (40%)

**Main Topics Examined:**

Mass Spectrometry, Amount of Substance, Redox, Kinetics,

Rate Equations

**Advice:**

1. Read the questions carefully - look out for tricks.
2. Some questions are harder than the A-level standard.
3. Apply existing knowledge to unfamiliar questions.
4. Check the fully worked solutions for any questions you missed.

**Section A: Multiple choice**. You are advised to spend no more than **30 minutes** in Section A.

1. Naturally occurring chlorine is a mixture of two isotopes with mass number 35 and 37. The isotope with mass number 35 is three times as common as the isotope with mass number 37. Naturally occurring bromine is a mixture of two isotopes with mass numbers 79 and 81. They are present in equal amounts.

   What fraction of naturally occurring compound $CH_2BrCl$ has a relative molecular mass of 128?

   O 1/8
   O 1/4
   O 3/8
   O 5/8 [1 mark]

2. The table shows some physical properties of four substances.

| *substance* | *melting point / °C* | *boiling point / °C* | *electrical conductivity* | |
|---|---|---|---|---|
| | | | *when solid* | *when molten* |
| **A** | 1700 | 2200 | none | none |
| **B** | 800 | 1470 | none | good |
| **C** | 98 | 880 | good | good |
| **D** | −20 | 58 | none | none |

   Which substance could have a giant covalent structure?

   O **A**
   O **B**
   O **C**
   O **D** [1 mark]

3. Which of these species is **not** planar?

   O $CH_3^+$
   O $SO_3$
   O $ClO_3^-$
   O $XeF_4$ [1 mark]

4. The heat energy change for a reaction is -100 kJ $mol^{-1}$, and the activation energy is +150 kJ $mol^{-1}$. The activation energy for the reverse reaction is

O -250 kJ $mol^{-1}$
O -50 kJ $mol^{-1}$
O +50 kJ $mol^{-1}$
O +250 kJ $mol^{-1}$ [1 mark]

5. The reaction between nitrogen and hydrogen to form ammonia is exothermic.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H$ is negative

The bond energies in the three molecules are as shown.

| | |
|---|---|
| N ≡ N | $x$ kJ $mol^{-1}$ |
| H – H | $y$ kJ $mol^{-1}$ |
| N – H | $z$ kJ $mol^{-1}$ |

Which statement can be correctly deduced from this information?

O $z > x + y$
O $2z > x + 3y$
O $6z > x + y$
O $6z > x + 3y$ [1 mark]

6. Photochromic glass contains silver ions and copper ions. A simplified version of the redox equilibrium is shown below.

$Cu^+ (s) + Ag^+ (s) \rightleftharpoons Cu^{2+} (s) + Ag (s)$

In bright sunlight the high energy UV light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

When the photochromic glass darkens,

o the $Ag^+$ ion is acting as an electron donor.
o the $Cu^+$ ion is acting as a reducing agent.
o the $Ag^+$ ion is oxidised.
o the $Cu^+$ ion is reduced. [1 mark]

7. The secondary alcohol **A** is oxidised by hexacyanoferrate(III) ions, $Fe(CN)_6^{3-}$, in the presence of ruthenate(VI) ions ($RuO_4^{2-}$) acting as a catalyst. The product of this conversion is ketone **B**.

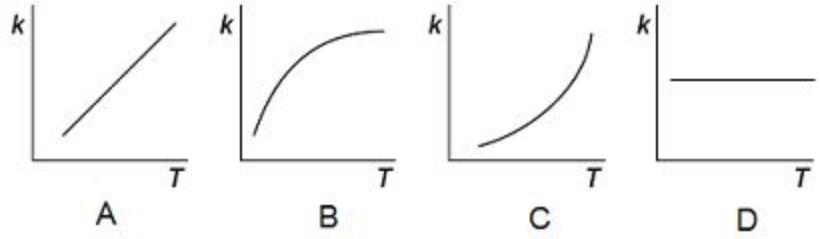
A series of experiments was conducted to investigate the kinetics of this reaction. The following initial rate data was obtained.

| Experiment | Initial [**A**] (mol $dm^{-3}$) | Initial $[Fe(CN)_6^{3-}]$ (mol $dm^{-3}$) | Initial $[RuO_4^{2-}]$ (mol $dm^{-3}$) | Initial rate (mol $dm^{-3}$ $s^{-1}$) |
|---|---|---|---|---|
| 1 | 1.64 | 0.200 | 0.800 | $4.10 \times 10^{-3}$ |
| 2 | 3.28 | 0.200 | 2.40 | $8.20 \times 10^{-3}$ |
| 3 | 4.92 | 0.400 | 2.40 | $4.92 \times 10^{-2}$ |
| 4 | 6.56 | 0.600 | 4.80 | $1.48 \times 10^{-1}$ |

The data in the table suggests a rate equation of the form

- o rate = $k$ [**A**] $[Fe(CN)_6^{3-}]$
- o rate = $k$ [**A**] $[Fe(CN)_6^{3-}]^2$
- o rate = $k$ [**A**] $[RuO_4^{2-}]$
- o rate = $k$ $[Fe(CN)_6^{3-}]$ $[RuO_4^{2-}]$ [1 mark]

8. Consider the four graphs below.




Which of the above graphs shows how the rate constant $k$ of a reaction varies with temperature $T$?

- O A
- O B
- O C
- O D [1 mark]

9. Consider the equilibrium shown below.

$CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$

The standard enthalpies of formation of the species are shown in the table.

| Substance | CO(g) | $H_2O(g)$ | $CO_2(g)$ | $H_2(g)$ |
|---|---|---|---|---|
| $\Delta H_f^{\ominus}$ / kJ mol$^{-1}$ | −110 | −242 | −394 | 0 |

Which of the three statements below are true?

**1** The value of $K_p$ changes when the temperature changes.
**2** The entropy change is more positive when the water is liquid rather than gaseous.
**3** The enthalpy change is more positive when the water is liquid rather than gaseous.

O **1** and **2** only
O **2** and **3** only
O **1** and **3** only
O **1**, **2** and **3** [1 mark]

10. A 2.5 g sample of ethanedioic acid, $H_2C_2O_4 \cdot nH_2O$, was dissolved and the solution was made up to 250 cm$^3$ with water. Titration of this solution against a 25 cm$^3$ standard 0.1 M NaOH solution required 15.8 cm$^3$ of ethanedioic acid for complete neutralisation.

The value of *n* is

O 1
O 2
O 4
O 8 [1 mark]

11. A fixed amount $n$ of a gas is held at constant pressure $p$ and temperature $T$.

If the most probable energy of the gas particles is $E_{mp}$ and the mean energy of the gas particles is $E_{mean}$, then

O $E_{mp} > E_{mean}$
O $E_{mean}$ and $E_{mp}$ are both dependent on $T$
O $E_{mean}$ and $E_{mp}$ are both dependent on $p$
O $E_{mean}$ and $E_{mp}$ are both dependent on $n$ [1 mark]

12. The following tests were carried out on separate samples of two monoprotic acids, HX and HY. HX is a strong acid and HY is a weak acid. Both acids had a concentration of 1.00 mol $dm^{-3}$.

**1** Measure the time taken for a 1 cm strip of magnesium to react completely when added to 25 $cm^3$ of each acid.
**2** Measure the volume of 1.00 mol $dm^{-3}$ sodium hydroxide solution needed to completely neutralise 20 $cm^3$ of each acid.
**3** Measure the electrical conductance of each acid using circuit apparatus.

Each test was carried out under the same conditions.

Which of the tests, considered independently, would show that HX was a stronger acid than HY?

o Tests **1** and **2** only
o Tests **2** and **3** only
o Tests **1** and **3** only
o All of tests **1**, **2** and **3** [1 mark]

13. A student is performing a titration to find out the concentration of a sample of sodium hydroxide solution given a standard solution of hydrochloric acid. Using a pipette, the student measures 25 $cm^3$ of the NaOH solution into a conical flask and fills the burette with 50 $cm^3$ 1.0 M HCl.

Which of these washing steps (done beforehand), if any, would increase the accuracy of the student's titration results?

**1** Rinse the conical flask with distilled water
**2** Rinse the burette with the NaOH solution

O **1** only
O **2** only
O Both **1** and **2**
O Neither **1** nor **2** [1 mark]

14. The oxidation states of the transition metal in the compounds $CrO_2F_2$, $K_2Mn_2O_7$ and $BaTiO_3$ respectively, are

O +6, +6, +4
O +2, +7, +3
O +4, +5, +4
O +6, +4, +3 [1 mark]

15. The dynamic equilibrium shown below is reached at temperature $T$ K with all species at standard pressure.

$2\ \mathbf{A}\ (g) + \mathbf{B}\ (g) \rightleftharpoons \mathbf{C}\ (g)$

The forward reaction is second-order with respect to **A** and first-order with respect to **B**, and the backward reaction is first-order with respect to **C**.

$K_c$ is the equilibrium constant at temperature $T$, and $\Delta G^{\ominus}$ is the standard Gibbs free energy change for the equilibrium. By considering the forward and backward rate constants for this equilibrium, it can be deduced that

(Useful identities: $e^a/e^b = e^{a-b}$ ; $\ln(e^a) = a$. $R$ is the gas constant in J $mol^{-1}$ $K^{-1}$.)

O $\Delta G^{\ominus} = RT \ln K_c$
O $\Delta G^{\ominus} = -RT \ln K_c$
O $\ln K_c = RT\ \Delta G^{\ominus}$
O $\ln K_c = -RT\ \Delta G^{\ominus}$ [1 mark]

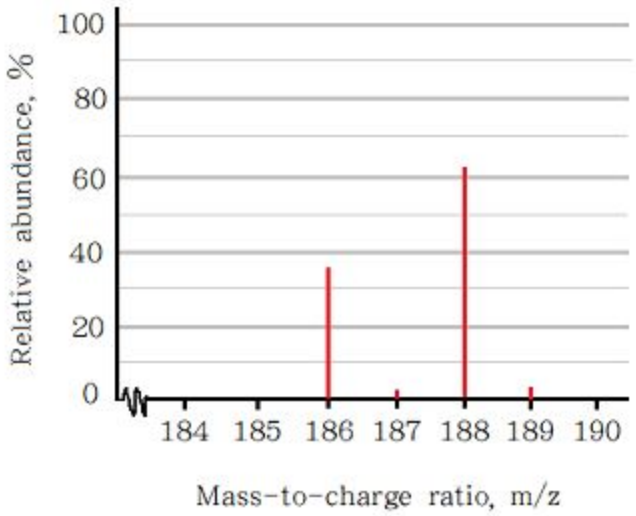
**Section B: Standard questions**. You are advised to spend **most** of your time in Section B.

16. A sample of element X was analysed in a time-of-flight mass spectrometer after soft ionisation to $HX^+$ ions. It is known that the original sample was composed solely of $^{185}X$ and $^{187}X$ isotopes.

a. Describe how a sample of X is ionised, accelerated and detected using this particular method of TOF spectrometry. [5 marks]

b. The $H^{185}X^+$ molecular ions had a recorded flight time of $2.446 \times 10^{-4}$ seconds. Calculate the time of flight of the $H^{187}X^+$ molecular ions. [6 marks]

c. The mass spectrum of the TOF analysis is shown below.




i) Use the mass spectrum to identify element X. [2 marks]

ii) Suggest why there are small peaks at *m*/*z* = 187 and 189. [1 mark]

[Total for Q16: 14 marks]

17. A white solid is a mixture of sodium ethanedioate ($Na_2C_2O_4$), ethanedioic acid dihydrate ($H_2C_2O_4 \cdot 2H_2O$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 $cm^3$ of aqueous solution. Two different titrations were carried out using this solution.

In the first titration 25.0 $cm^3$ of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 $^oC$ and then titrated with a 0.0200 mol $dm^{-3}$ solution of potassium manganate(VII). When 26.50 $cm^3$ of potassium manganate(VII) had been added, the solution changed colour due to the presence of $Mn^{2+}$ ions and effervescence was observed.

a. i) Write down the molecular formula of potassium manganate(VII). [1 mark]

ii) Derive half equations for the separate reduction and oxidation of manganate(VII) ions and ethanedioate ions, and combine them to form the overall ionic equation. [3 marks]

In the second titration 25.0 $cm^3$ of the solution was titrated with a 0.100 mol $dm^{-3}$ solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 $cm^3$ of sodium hydroxide solution.

b. Derive the ionic equation for this reaction. [2 marks]

c. Using your equations above and the titration data, calculate the percentage by mass of sodium ethanedioate in the white solid. Give your answer to the appropriate number of significant figures. [8 marks]

[Total for Q17: 14 marks]

18. A student was asked to investigate the effect of temperature on the rate of a reaction. They were given a sample of 0.05 mol $dm^{-3}$ sodium thiosulfate solution ($Na_2S_2O_3$) and 1.0 mol $dm^{-3}$ hydrochloric acid.

These solutions react to form a soluble salt, a precipitate, a gas and liquid water.

a. i) Write an equation, including state symbols, for this reaction. [2 marks]

ii) Suggest how the student could tell when the endpoint of this reaction has been reached. [1 mark]

b. Describe a method the student could undertake to investigate the qualitative effect of temperature on the rate of reaction. [6 marks]

[Total for Q18: 8 marks]

19. In this question, you may use the Arrhenius equation and its rearrangement, i.e.

$$k = A \exp\left(-\frac{E_a}{RT}\right) \qquad \text{and} \qquad \ln k = \ln A - \frac{E_a}{RT}$$

and may refer to them without proof. The gas constant, $R$ = 8.31 J mol$^{-1}$ K$^{-1}$. Throughout this question, you may assume that the Arrhenius constant $A$ is independent of temperature.

A certain reaction has an activation energy of 50 kJ.

a. Show that, for this reaction at 25 °C, the rate of the reaction approximately doubles when the temperature is increased by 10 °C at the same concentrations of reagents. [4 marks]

b. The rule of thumb that increasing temperature 10 °C doubles the rate does not hold at temperatures significantly higher or lower than standard conditions.

Find the lowest temperature $T$ above which an increase by 10 °C leads to the rate increasing by a factor less than 1.5. [6 marks]

c. Rates can also be influenced by concentrations. The extent to which concentration affects rate is indicated by the order of reaction. For most reactions, the order is a whole number such as 0, 1 or 2.

Some reactions can have fractional (non-integer) orders. A fractional order often indicates a more complex mechanism such as a chain reaction. The thermal decomposition of ethanal in an inert atmosphere into methane and carbon monoxide proceeds with an order of 1.5 with respect to ethanal.

i) Write the symbol equation for this reaction. [1 mark]

ii) Write down the rate equation for this reaction. [1 mark]

Most thermal decomposition reactions are known to proceed by free-radical mechanisms. The initiation step for the thermal decomposition of ethanal involves the homolytic fission of the carbon-carbon bond, i.e.

$CH_3CHO \rightarrow \ \bullet CH_3 + \bullet CHO$

iii) Draw dot-and-cross structures of each of these radicals, showing the unpaired electron in each case.

You may find it helpful to first draw the structure of ethanal. [2 marks]

iv) Suggest a propagation step for the reaction of a methyl radical in this scenario. Draw the dot-and-cross structure of the free radical formed in this step and show its unpaired electron. [2 marks]

v) Suggest the second propagation step for this reaction. [1 mark]

d. The order of 1.5 can be justified by first assuming that, during the reaction, the rates of formation and destruction of methyl radicals are equal, and that the only major termination step is 2 $\bullet CH_3 \rightarrow C_2H_6$. It is also assumed that, for any reaction that occurs in a single step (e.g. the initiation step), the order of reaction with respect to a particular reactant equals the stoichiometric coefficient for that reactant.

Let $k_i$ and $k_t$ be the rate constants for the initiation and termination step of this reaction respectively.

i) Show that $k_i [CH_3CHO] - k_t [\bullet CH_3]^2 = 0$. [4 marks]

ii) Show that this implies that $[\bullet CH_3]$ is proportional to $[CH_3CHO]^{1/2}$. [2 marks]

iii) Hence, and by considering the rate of formation of methane, show that the overall order of the reaction is 1.5. [4 marks]

[Total for Q19: 27 marks]

20. 10 $cm^3$ of a gaseous hydrocarbon, $C_xH_y$, were injected into a gas syringe and exploded with an excess of atmospheric oxygen inside an oven at temperature *T* K, where *T* > 373. There was an **increase** in volume of 5 $cm^3$.

When the products were treated with an excess of aqueous sodium hydroxide solution, there was a **reduction** in volume of 30 $cm^3$. Assume the volume change due to the partial evaporation of the sodium hydroxide solution is negligible.

a. i) Write an equation, with state symbols, for the reaction of the products of the explosion with aqueous sodium hydroxide at temperature *T*.

[2 marks]

ii) Explain why there is a contraction in volume when the sodium hydroxide is added to the gaseous products. [1 mark]

b. Deduce the molecular formula of the hydrocarbon, assuming that all volumes were measured under the same conditions.

You may find it useful to write a balanced equation for the explosion with stoichiometric coefficients in terms of *x* and *y*. [9 marks]

[Total for Q20: 12 marks]

**End of Questions**

## Question Sources

| | |
|---|---|
| Q1: | AQA A-Level Chemistry Past Paper |
| Q2: | NSAA Past Paper (Chemistry) |
| Q3: | AQA A-Level Chemistry Past Paper |
| Q4, 5, 6: | NSAA Past Paper (Chemistry) |
| Q8: | NSAA Past Paper (Chemistry) |
| Q9: | AQA A-Level Chemistry Past Paper |
| Q12: | NSAA Past Paper (Chemistry) |
| Q14: | IIT Advanced Past Paper (Chemistry) |
| | |
| Q17, 18: | AQA A-Level Chemistry Past Paper |
| Q20: | ChemSheets Challenge |