# College Board AP® Chemistry
# Section II: Free Response (Set B)

**Saturday 20 June 2026**

**Afternoon (Time: 1 hour 45 minutes)**

Total Marks **/ 46**

**Instructions**

- Try to complete this mock exam paper in one sitting, under exam conditions. Use all the time available and check your answers to each question at the end before submitting.
- Remember this is PRACTICE. Mistakes are fine and will help you improve in time for the real exam - just do your best.
- There are 3 long questions (10 marks each) and 4 short questions (4 marks each)
- Show all your working
- You are expected to use a scientific calculator where appropriate

**Materials**

- a pencil and a ruler
- a scientific calculator
- a Periodic table
- an AP chemistry equations and constants sheet

**Scan here to mark your mock exam**
or visit the mock exams landing page for this course

**1 (a)** A sample of element Y is analyzed in the laboratory. It has an atomic number of 12 and two common isotopes: Y-24 and Y-25.

Write the complete electron configuration for a neutral atom of element Y.

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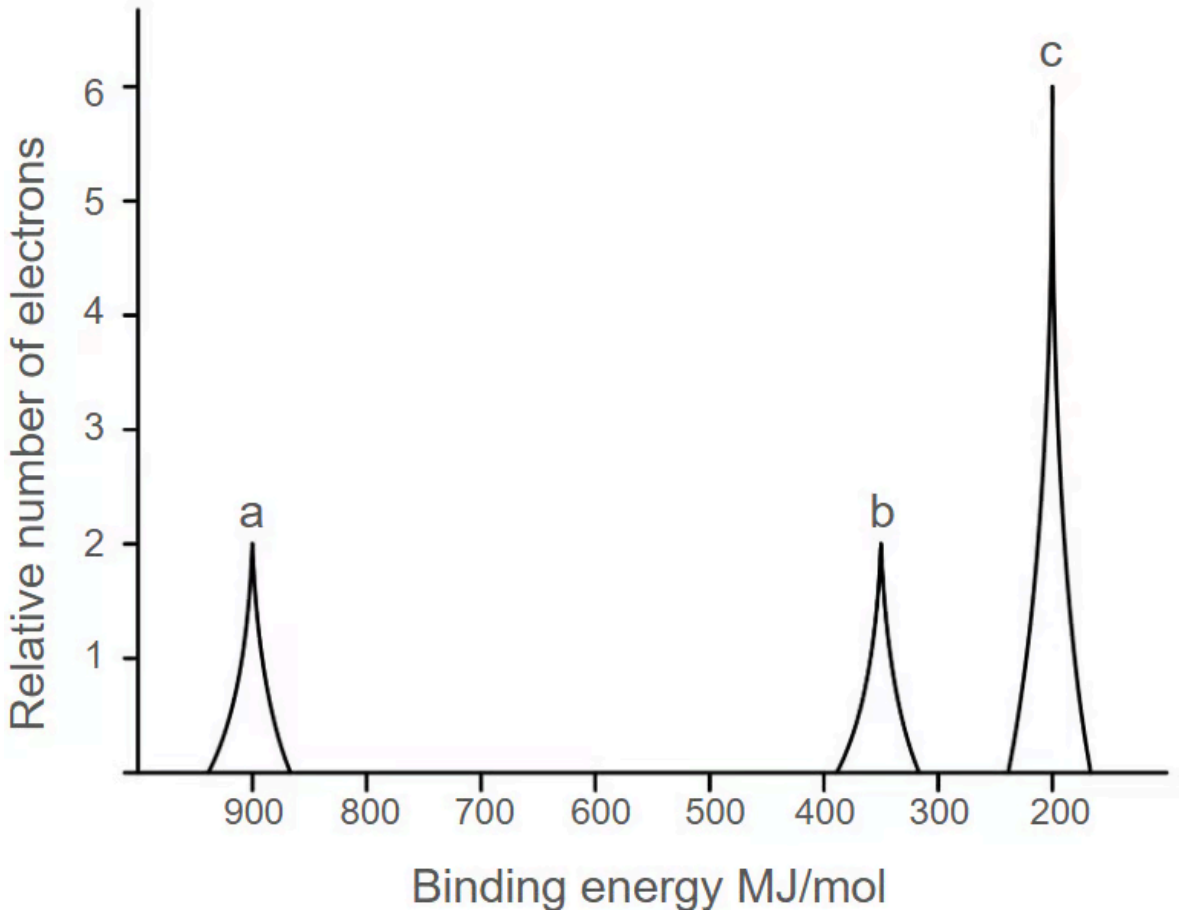
**(1 mark)**

**(b)** The photoelectron spectrum of element Y includes three peaks labeled A, B, and C.




Identify the electron subshell that corresponds to each peak. Justify your answer.

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**(2 marks)**

**(c)** The sample also contains the isotope Y-25.

i) Define the term isotope.

ii) Explain how the mass spectrum of Y would reflect the presence of both isotopes.

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..... **(2 marks)**

**(d)** The first three ionization energies of element Y are shown in the table below.

| Ionization level | Ionization energy (kJ/mol) |
|---|---|
| 1st | 738 |
| 2nd | 1450 |
| 3rd | 7730 |

Using this data, determine the number of valence electrons in element Y. Justify your answer.

..... **(1 mark)**

**(e)** Explain why the third ionization energy of element Y is significantly higher than the first and second.

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..... **(2 marks)**

**(f)** Element Z has an atomic number of 13. Predict which element, Y or Z, has the greater atomic radius. Justify your answer.

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..... **(2 marks)**

**2 (a)** A student investigates the energy changes that occur when potassium chloride (KCl) dissolves in water. The student adds 4.00 g of solid KCl to 100.0 g of distilled water in a calorimeter and records the temperature change over time. The calorimeter has negligible heat loss, and the specific heat capacity of water is 4.18 J $g^{-1}$ $^{o}C^{-1}$.

The temperature of the water changes from 24.6 $^{o}C$ to 21.3 $^{o}C$ after the KCl dissolves completely.

Write the balanced chemical equation, including state symbols, that represents the dissolution of solid KCl in water.

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**(1 mark)**

**(b)** Is the dissolution of KCl endothermic or exothermic? Justify your answer using the data from the experiment.

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**(1 mark)**

**(c)** Using the data from the experiment, calculate the amount of heat energy transferred (q) as the KCl dissolves in water. Assume the solution has the same specific heat capacity and mass as the water.

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**(2 marks)**

**(d)** Use your answer from part (c) to calculate the molar enthalpy change ($\Delta H$, in kJ $mol^{-1}$) for the dissolution of KCl.

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**(3 marks)**

**(e)** Explain the thermodynamic reason why the dissolution of KCl occurs, even though the temperature of the solution decreases.

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**(2 marks)**

**(f)** If the same amount of KCl were dissolved in only 50.0 g of water, would the temperature change of the solution be greater, smaller, or the same? Justify your answer.

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**(1 mark)**

**3 (a)** Consider the following reaction mechanism:

1. $NO + O_3 \rightarrow NO_2 + O_2$ (fast)

2. $NO + NO_2 \rightarrow N_2O_3$ (slow)

The overall reaction releases energy as products form. Write the overall balanced chemical equation for this reaction.

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**(1 mark)**

**(b)** Draw the energy profile for this mechanism, clearly labelling the activation energy ($E_a$) for each step, the intermediate, and $\Delta H$.

**(3 marks)**

**(c)** Justify why the first step has a lower activation energy than the second step.

.....

**(1 mark)**

**(d)** Explain how the addition of a catalyst changes the energy profile and the reaction rate.

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**(2 marks)**

**(e)** Explain how increasing the concentration of $NO_2$ would affect the overall rate of the reaction. Justify your answer.

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**(1 mark)**

**(f)** A student proposes using temperature to speed up the reaction. Predict how increasing the temperature affects the fraction of collisions with energy ≥ $E_a$ and explain the molecular basis of this change.

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.....(2 marks)

**4 (a)** Two buffer solutions are prepared:

- Buffer 1: 1.00 *M* $CH_3COOH$ + 1.00 *M* $CH_3COO^-$
- Buffer 2: 0.10 *M* $CH_3COOH$ + 0.10 *M* $CH_3COO^-$

A student adds 0.05 moles of HCl to both 1.0 L buffer solutions.

Define buffer capacity.

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**(1 mark)**

**(b)** Predict which buffer in part (a) will experience a smaller pH change upon HCl addition and justify your answer.

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**(1 mark)**

**(c)** Explain why the ratio of $[CH_3COO^-]$ to $[CH_3COOH]$ remains nearly constant in Buffer 1 in part (a).

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**(1 mark)**

**(d)** Use Le Châtelier's principle to explain how the addition of HCl affects the equilibrium in buffer 2.

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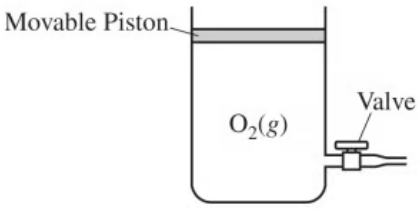
**(1 mark)**

**5 (a)**




A student investigates gas behavior using a rigid cylinder with a movable piston of negligible mass, as shown in the diagram above. The cylinder contains 0.325 mol of $O_2$ (g) and has a volume of 7.95 L at 25°C and 1.00 atm .

Calculate the density of the $O_2$ (g), in g/L, under these conditions.

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**(1 mark)**

**(b)** Attempting to change the density of the $O_2$ (g), the student opens the valve on the side of the cylinder, pushes down on the piston to release some of the gas, and closes the valve again. The temperature of the gas remains constant at 25°C. Will this action change the density of the gas remaining in the cylinder? Justify your answer.

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**(1 mark)**

**(c)** The student tries to change the density of the $O_2$ (g) by cooling the cylinder to − 55°C, which causes the volume of the gas to decrease. Using principles of kinetic molecular theory, explain why the volume of the $O_2$ (g) decreases when the temperature decreases to − 55°C.

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**(1 mark)**

**(d)** The student further cools the cylinder to − 180°C and observes that the measured volume of the $O_2$ (g) is substantially smaller than the volume that is calculated using the ideal gas law. Assume all equipment is functioning properly. Explain why the measured volume of the $O_2$ (g) is smaller than the calculated volume. (The boiling point of $O_2$ (l) is − 183°C.)

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**(1 mark)**

**6 (a)** Explain how London dispersion forces arise in nonpolar molecules.

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**(1 mark)**

**(b)** Rank the following noble gases in order of increasing boiling point: He, Ne, Ar, Kr, Xe. Justify your ranking.

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**(2 marks)**

**(c)** Pentane ($C_5H_{12}$), 2-methylbutane ($C_5H_{12}$), and 2,2-dimethylpropane ($C_5H_{12}$) all have the same molecular formula.

Predict which has the highest boiling point and justify your answer based on intermolecular forces.

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**(1 mark)**

**7 (a)** Answer the following questions about the solubility of $Ca(OH)_2$ ($K_{sp} = 1.3 \times 10^{-6}$).

Write a balanced chemical equation for the dissolution of $Ca(OH)_2$ (*s*) in pure water.

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**(1 mark)**

**(b)** Calculate the molar solubility of $Ca(OH)_2$ in 0.10 *M* $Ca(NO_3)_2$ .

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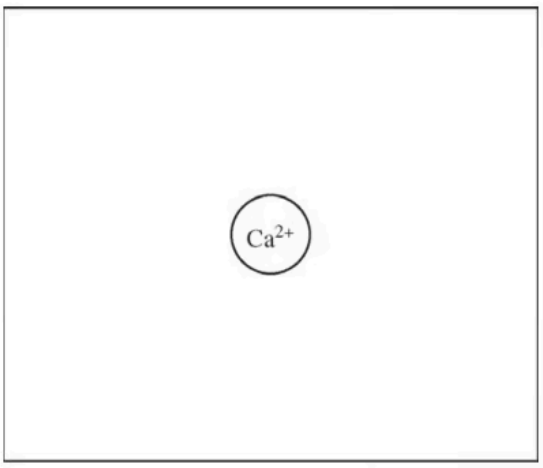
**(2 marks)**

**(c)** In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the $Ca^{2+}$ ion.

Represent water molecules as




**(1 mark)**