Chemistry
Higher level
Paper 1

11 May 2023

Zone A afternoon │ **Zone B** morning │ **Zone C** afternoon

1 hour

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is **[40 marks]**.

The Periodic Table

Key:

Atomic number
Element
Relative atomic mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Unt** (286)	114 **Uuq** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

† Lanthanides:

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97

‡ Actinides:

| 90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. What is the mass of one molecule of C_{60}?

$$N_A = 6.0 \times 10^{23}$$

A. 1.0×10^{-22} g

B. 2.0×10^{-23} g

C. 8.3×10^{-24} g

D. 1.2×10^{-21} g

2. $20\,cm^3$ of gas A reacts with $20\,cm^3$ of gas B to produce $10\,cm^3$ of gas A_xB_y and $10\,cm^3$ of excess gas A. What are the correct values for subscripts **x** and **y** in the empirical formula of the product $A_xB_y\,(g)$?

|	**x**	**y**
A.	2	1
B.	2	2
C.	1	1
D.	1	2

3.   The volume *V* for a fixed mass of an ideal gas was measured at constant temperature at different pressures *p*. Which graph shows the correct relationship between *pV* against *p*?

A.

B.

C.

D.
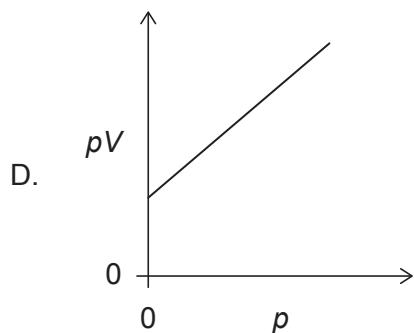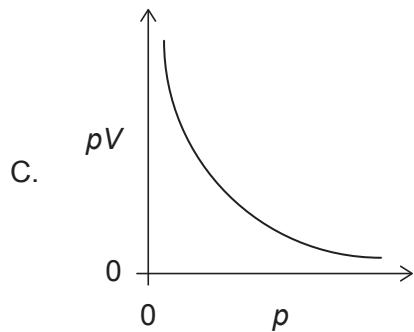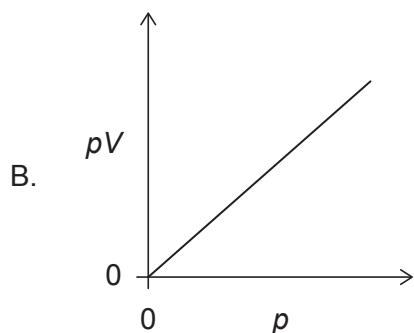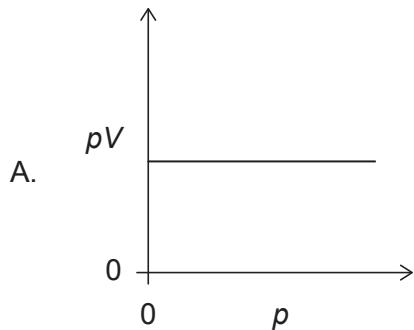
4. What is the correct ground state electron orbital configuration for $2s^2 2p^2$?

2s   **2p**

A. ↑↓   ↑   ↑

B. ↑↓   ↑   ↓

C. ↑↑   ↑   ↑

D. ↑↑   ↑   ↓
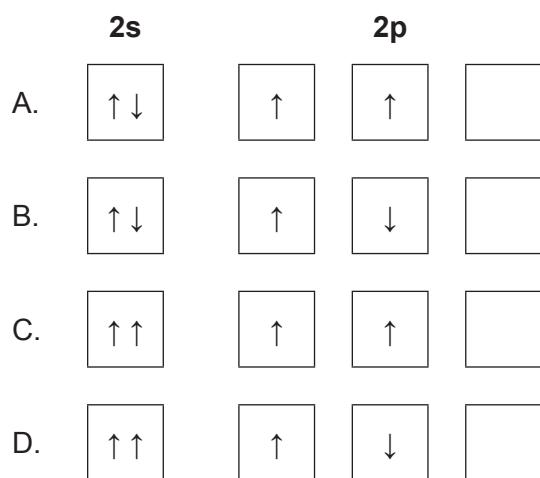
5. The successive ionization energies for an element in period three are shown.
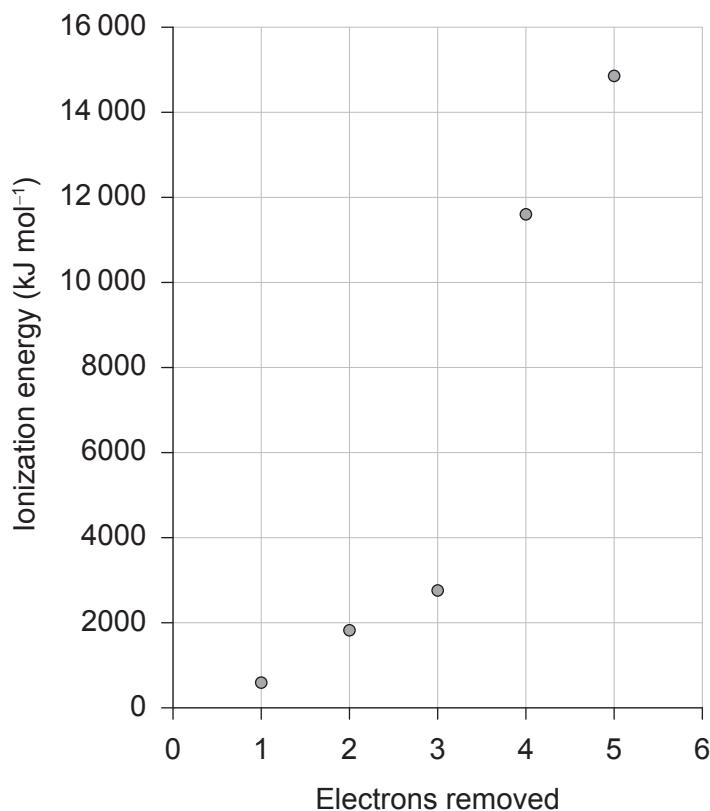
Which element in period 3 has these successive ionization energies?

A. Na

B. Mg

C. Al

D. Si

Turn over

6. Which sequence has the oxides arranged in order of increasing acidity?

A. $Na_2O \; < \; Al_2O_3 \; < \; SO_3$

B. $Al_2O_3 \; < \; SO_3 \;\; < \; Na_2O$

C. $SO_3 \;\; < \; Na_2O \; < \; Al_2O_3$

D. $SO_3 \;\; < \; Al_2O_3 \; < \; Na_2O$

7. Which properties increase down the group 1 alkali metals?

    I.   atomic radii

    II.   melting point

    III.   reactivity with water

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

8. Which of these factors explains why $NiCl_4^{2-}$ and $CoCl_4^{2-}$ have different colours?

A.   Identity of the metal ion

B.   Charge on the metal ion

C.   Identity of the ligand in the complex

D.   Spectrochemical series

9. Which compound has an element with an incomplete octet of electrons?

A. BF_3

B. CF_4

C. OF_2

D. ClF_3

10. What is the correct sequence if the compounds are arranged in order of increasing boiling point?

    A. CH_3OCH_3 < CH_3CH_2OH < CH_3CHO

    B. CH_3OCH_3 < CH_3CHO < CH_3CH_2OH

    C. CH_3CHO < CH_3CH_2OH < CH_3OCH_3

    D. CH_3CHO < CH_3OCH_3 < CH_3CH_2OH

11. What is the correct comparison of H—N—H bond angles in NH_2^-, NH_3, and NH_4^+?

    A. NH_2^- < NH_3 < NH_4^+

    B. NH_4^+ < NH_3 < NH_2^-

    C. NH_3 < NH_2^- < NH_4^+

    D. NH_3 < NH_4^+ < NH_2^-

12. Which is the valid and preferred Lewis structure of the $NO_2\bullet$ radical, based on formal charge?

    A.

    B.

    C.

    D.
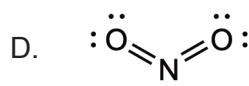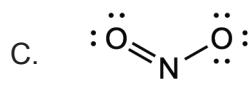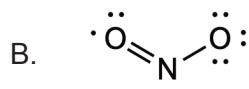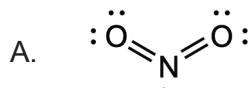
13. Which wavelength and energy of light will break bonds in ozone rather than oxygen molecules?

    A.   Shorter wavelength and lower energy

    B.   Shorter wavelength and higher energy

    C.   Longer wavelength and lower energy

    D.   Longer wavelength and higher energy

Turn over

14. The enthalpy of formation of ammonia gas is $-46 \, \text{kJ mol}^{-1}$.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$
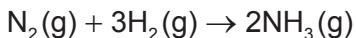
What is the energy released, in kJ, in the reaction?

A.   23

B.   46

C.   69

D.   92

15. When $100 \, \text{cm}^3$ of $1.0 \, \text{mol dm}^{-3}$ HCl is mixed with $100 \, \text{cm}^3$ of $1.0 \, \text{mol dm}^{-3}$ NaOH, the temperature of the resulting solution increases by $5.0 \, °C$. What will be the temperature change, in $°C$, when $50 \, \text{cm}^3$ of $2.0 \, \text{mol dm}^{-3}$ HCl is mixed with $50 \, \text{cm}^{-3}$ of $2.0 \, \text{mol dm}^{-3}$ NaOH?

A.   2.5

B.   5.0

C.   10

D.   20

16. Which of these changes involve an increase in entropy?

A. $Cl(g) + e^- \rightarrow Cl^-(g)$ and $Li(g) \rightarrow Li^+(g) + e^-$

B. $Li(s) \rightarrow Li(g)$ and $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

C. $Cl(g) \rightarrow \dfrac{1}{2}Cl_2(g)$ and $Li(s) \rightarrow Li(g)$

D. $\dfrac{1}{2}Cl_2(g) \rightarrow Cl(g)$ and $Li(s) \rightarrow Li(g)$

17. Which is correct when $\Delta H - T\Delta S = 0$?

A.   Forward reaction is favoured.

B.   Reverse reaction is favoured.

C.   Reaction is in a state of equilibrium.

D.   No chemical changes can occur.

18. Curve **X** on the following graph shows the volume of oxygen formed during the catalytic decomposition of a 1.0 mol dm^{-3} solution of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$$
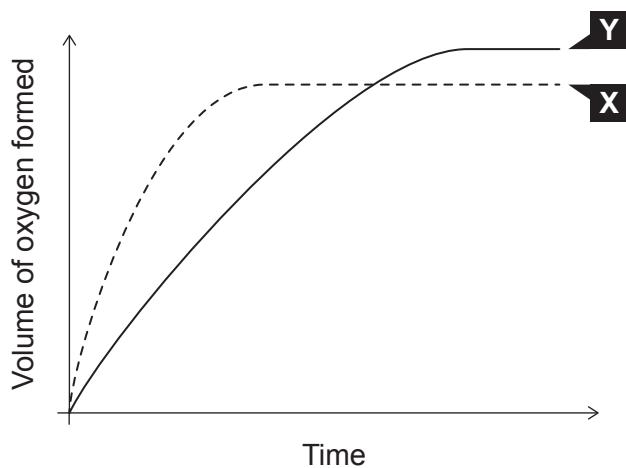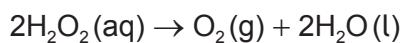
Which change would produce the curve **Y**?

A.   Adding water.

B.   Adding some 0.1 mol dm^{-3} hydrogen peroxide solution.

C.   Adding some 2.0 mol dm^{-3} hydrogen peroxide solution.

D.   Repeating the experiment without a catalyst.

19. Which two colliding species have the highest probability of having the proper orientation for a reaction to occur?

    A. $Cl\bullet + Cl\bullet$

    B. $Cl\bullet + CH_3\bullet$

    C. $HCl + CH_2{=}CH_2$

    D. $CF_3Cl + O_3$

20. Which proposed mechanism for the following reaction is consistent with the rate law?

$$2NO\,(g) + F_2\,(g) \rightarrow 2NOF\,(g) \quad Rate = k[NO][F_2]$$

A.

Step 1 (slow)	Step 2 (fast)
$NO + F_2 \rightarrow NOF + F$	$F + NO \rightarrow NOF$

B.

Step 1 (fast)	Step 2 (slow)
$NO + F_2 \rightarrow NOF + F$	$F + NO \rightarrow NOF$

C.

One step
$NO + NO + F_2 \rightarrow 2NOF$

D.

Step 1 (slow)	Step 2 (fast)
$NO + NO \rightarrow N_2O_2$	$N_2O_2 + F_2 \rightarrow 2NOF$

21. Which value increases when the temperature of a reaction increases?

    A.   Activation energy

    B.   Rate constant

    C.   Enthalpy of reaction

    D.   Equilibrium constant for exothermic reaction

22. Which condition will cause the given equilibrium to shift to the right?

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s)$$
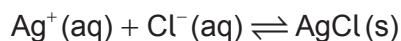
A.   One half of solid AgCl is removed.

B.   Water is added.

C.   Solid NaCl is added.

D.   The system is subjected to increased pressure.

23. Which values of equilibrium constant, K, and Gibbs free energy, ΔG, favour the reverse reaction of an equilibrium?

	Value of K	Value of ΔG
A.	>1	positive
B.	>1	negative
C.	<1	positive
D.	<1	negative

24. What is the order of increasing conductivity for aqueous solutions of these acids and bases at equal concentrations?

	pK_b
Methylamine	3.34
Ethanol	15.5
Phenylamine	9.13

A.   methylamine   <   ethanol   <   phenylamine

B.   ethanol   <   phenylamine   <   methylamine

C.   methylamine   <   phenylamine   <   ethanol

D.   ethanol   <   methylamine   <   phenylamine

25. Which graph represents the pH curve of a weak base titrated with a strong acid?

pH

7

A.

Volume of acid added

pH

7

B.

Volume of acid added

pH

7

C.

Volume of acid added

pH

7

D.

Volume of acid added
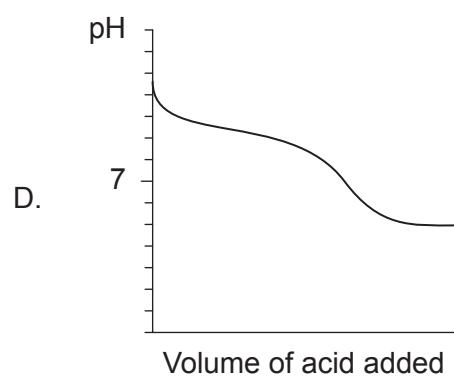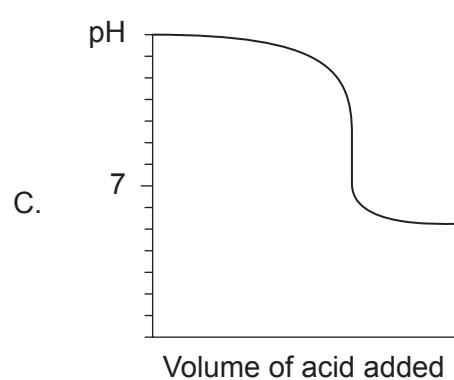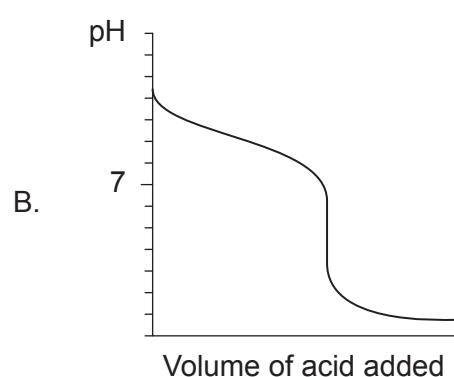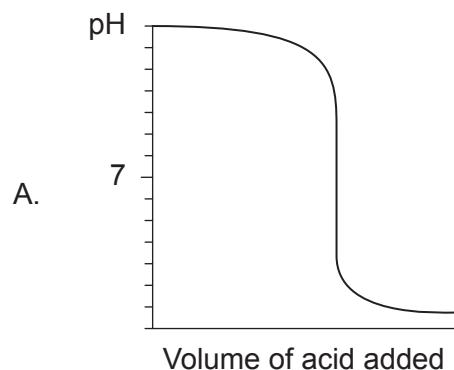
26. Which condition results in a buffer solution?

    A.   Complete neutralization of a strong acid with a strong base.

    B.   Complete neutralization of a weak acid with a weak base.

    C.   Partial neutralization of a strong acid with a weak base.

    D.   Partial neutralization of a weak acid with a strong base.

27. The ionic product constant of water, K_w, is 3×10^{-15} at $10\,°C$ and 5×10^{-13} at $98\,°C$. What is true about the hydrogen and hydroxide ion concentrations when pH $= 7$ at these temperatures?

	pH = 7 at 10 °C	pH = 7 at 98 °C
A.	$[H^+] = [OH^-]$	$[H^+] = [OH^-]$
B.	$[H^+] > [OH^-]$	$[H^+] > [OH^-]$
C.	$[H^+] < [OH^-]$	$[H^+] > [OH^-]$
D.	$[H^+] > [OH^-]$	$[H^+] < [OH^-]$

28. Which species is the oxidizing agent?

$$14H^+(aq) + 2Mn^{2+}(aq) + 5BiO_3^-(aq) \rightarrow 2MnO_4^-(aq) + 5Bi^{3+}(aq) + 7H_2O(l)$$
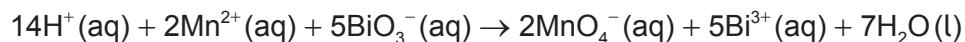
    A. $H^+(aq)$

    B. $Mn^{2+}(aq)$

    C. $BiO_3^-(aq)$

    D. $MnO_4^-(aq)$

29. Which chemical process would produce a voltaic cell?

    A.   spontaneous redox reaction

    B.   spontaneous non-redox reaction

    C.   non-spontaneous redox reaction

   D.   non-spontaneous non-redox reaction

30. Which combination of potential (voltage) is correct regarding the reduction and oxidation of the standard hydrogen electrode (SHE)?

	Reduction potential	Oxidation potential
A.	zero	zero
B.	zero	positive
C.	zero	negative
D.	negative	positive

31. Which will eventually yield the greatest mass of deposited copper in the electrolysis of a fixed volume of $1 \, mol \, dm^{-3} \, CuSO_4 \, (aq)$?

A.   copper anode and inert cathode

B.   inert anode and copper cathode

C.   inert anode and inert cathode

D.   zinc anode and zinc cathode

32. Which compound is an aromatic ester?

A.


B.

C.

D.
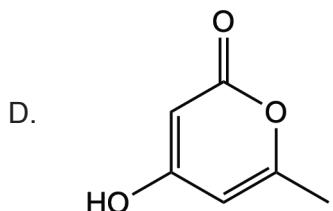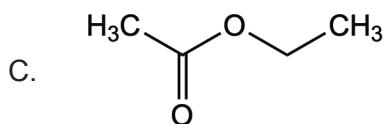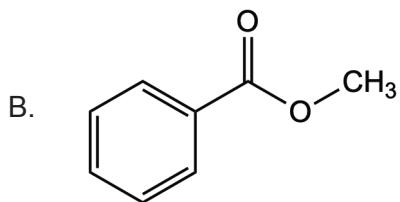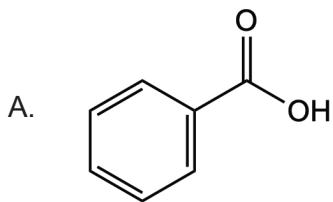
33. Which reaction mechanisms involve heterolytic fission of chlorine?

    I.   electrophilic addition

    II.   electrophilic substitution

    III.   nucleophilic substitution

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

34. What is the preferred IUPAC name of the structure shown?
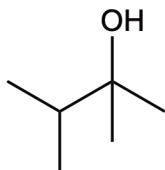
- A.   2-ethyl-3-methylbutan-1-ol

- B.   2,3-dimethylbutan-2-ol

- C.   1-ethyl-2-methylpropan-1-ol

- D.   1,1,2-trimethylpropan-1-ol

**35.** What is the correct order of reaction types in the following sequence?

$$C_3H_7Br \xrightarrow{\text{ I }} C_3H_7OH \xrightarrow{\text{ II }} C_2H_5COOH \xrightarrow{\text{ III }} C_2H_5CHO$$

	I	II	III
A.	substitution	oxidation	reduction
B.	addition	substitution	reduction
C.	oxidation	substitution	reduction
D.	substitution	oxidation	substitution

36. The observed specific optical rotation, $[\alpha]$, of a compound is $+7.00°$. What is the specific optical rotation of a racemate of this compound?

- A. $-7.00°$

- B. $0.00°$

- C. $+7.00°$

- D. $+14.00°$

37. Which mechanism does the nitration of benzene proceed by?

    A.   electrophilic addition

    B.   electrophilic substitution

    C.   nucleophilic addition

    D.   nucleophilic substitution

38. Which observation would explain a systematic error for an experiment involving the combustion of magnesium to find the empirical formula of its oxide?

    A.   The crucible lid was slightly ajar during heating.

    B.   The product was a white powdery substance.

    C.   The crucible had black soot on the bottom after heating.

    D.   The flame colour during heating was yellow.

39. Which technique is best for determining bond lengths within a molecule?

    A. ^{1}H NMR spectroscopy

    B.   infrared spectroscopy

    C.   mass spectroscopy

    D.   X-ray crystallography

40. The following graph shows the concentration of C_4H_9Cl versus time.
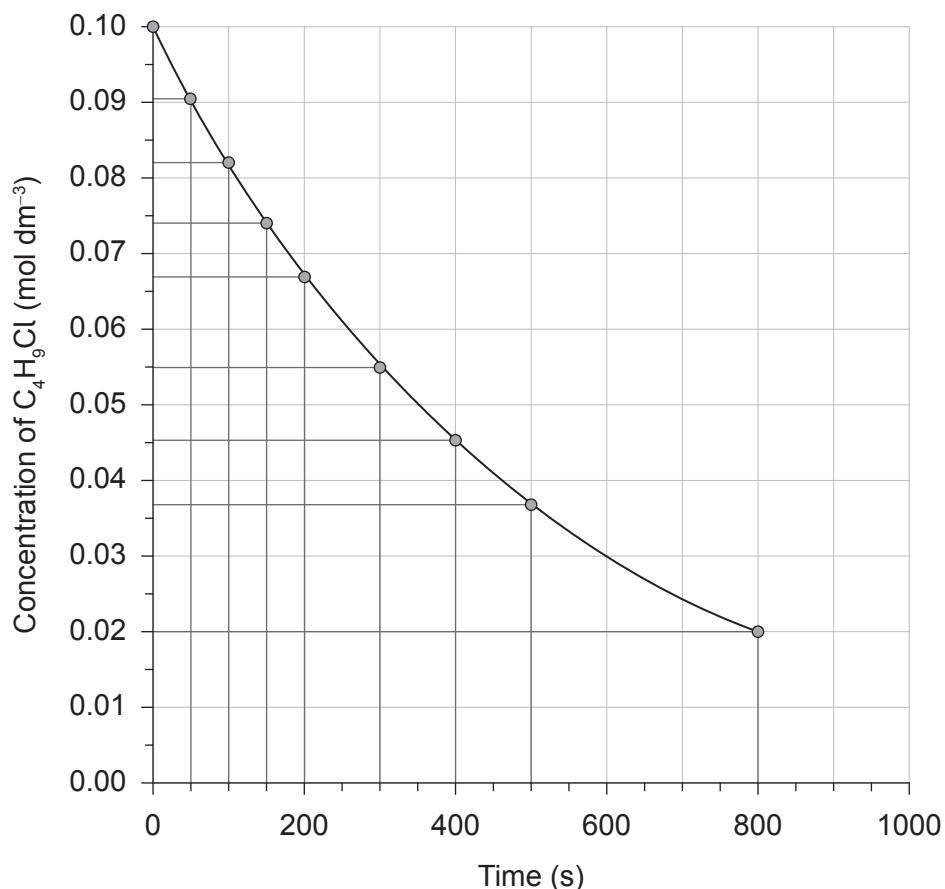
What is the average rate of reaction over the first 800 seconds?

A. $1 \times 10^{-3} \, mol \, dm^{-3} \, s^{-1}$

B. $1 \times 10^{-4} \, mol \, dm^{-3} \, s^{-1}$

C. $2 \times 10^{-3} \, mol \, dm^{-3} \, s^{-1}$

D. $2 \times 10^{-4} \, mol \, dm^{-3} \, s^{-1}$

References: