Diploma Programme
Programme du diplôme
Programa del Diploma

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]**.

2223 – 6107

19 pages

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01				Atomic number **Element** Relative atomic mass							5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	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
4	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
5	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
6	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)
7	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 **Uug** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	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
‡	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. Which information does the molecular formula provide?

A. The simplest ratio of atoms in a molecule

B. The actual numbers of atoms in a molecule

C. The number of molecules in one mole

D. The types of bonds in a molecule

2. A student heated a known mass of zinc powder in an open crucible until there was no further mass change and recorded the final mass.

What would the student be able to derive from this data?

I. Percentage composition of zinc oxide

II. Empirical formula of zinc oxide

III. Molecular formula of zinc oxide

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

3. What is the molar mass of a gas according to the following experimental data?

Mass of gas	40.0 g
Volume	220 cm^3
Temperature	17 °C
Pressure	98 kPa

Ideal gas constant = 8.31 J K^{-1} mol^{-1}
PV = nRT

A. $\frac{40.0 \times 8.31 \times 290}{98 \times 0.220}$

B. $\frac{98 \times 0.220}{40.0 \times 8.31 \times 290}$

C. $\frac{40.0 \times 8.31 \times 17}{98 \times 0.220}$

D. $\frac{98 \times 220}{40.0 \times 8.31 \times 17}$

4. What is the maximum number of electrons in energy level n = 4?

A. 8

B. 18

C. 32

D. 50

5. Which statement best explains the first ionization energy of sulfur being lower than that of phosphorus?

A. Sulfur has more protons than phosphorus.

B. Phosphorus does not have paired electrons in the outer p sub-level.

C. Sulfur has an unpaired electron in the outer p sub-level.

D. Phosphorus is more reactive than sulfur.

6. What can be deduced from the period number of an element?

I. Highest occupied energy level
II. Number of sub-levels in the outer shell
III. Number of outer electrons

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

7. In the following unbalanced equation, **X** represents an element.

Which oxide reacts with water as shown?

$$\_\_\_\_ + H_2O \rightarrow \mathbf{X}(OH)_2$$

A. Na_2O

B. MgO

C. NO_2

D. SO_3

8. Which element is not a transition metal?

A. Cr

B. Mn

C. Ni

D. Zn

9. Which substance is likely to have an ionic lattice structure at 298 K and 100 kPa?

	Melting point	Conducts electricity in a liquid state?
A.	low	yes
B.	low	no
C.	high	no
D.	high	yes

10. Why does the melting point of the elements decrease down group 1?

A. Atomic mass increases

B. Number of electrons increases

C. Radius of metal ion increases

D. First ionization energy decreases

11. In which molecule does the central atom have an incomplete octet of electrons?

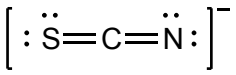
A. H_2Se

B. PH_3

C. OF_2

D. BF_3

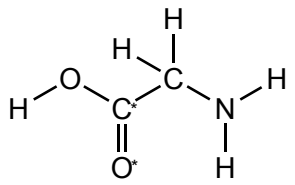
12. What are the formal charges on the atoms in this molecular ion?



	S	C	N
A.	–1	0	0
B.	0	0	–1
C.	–1	+1	0
D.	0	+1	–1

13. Which types of hybridization are present in glycine?

Glycine



	C*	N	O*
A.	sp^2	sp^3	sp^2
B.	sp^2	sp^3	sp
C.	sp	sp^2	sp^2
D.	sp	sp^2	sp

14. What is the enthalpy change for the following reaction?

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$$

Reaction	$\Delta H^{\ominus}$
$2C_{(graphite)} + O_2(g) \rightarrow 2CO(g)$	$-222\,kJ\ mol^{-1}$
$C_{(graphite)} + 2H_2(g) \rightarrow CH_4(g)$	$-74\,kJ\ mol^{-1}$
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$	$-484\,kJ\ mol^{-1}$

A. $-74 - 242 + 111$

B. $+74 + 242 - 111$

C. $-74 - 484 - 222$

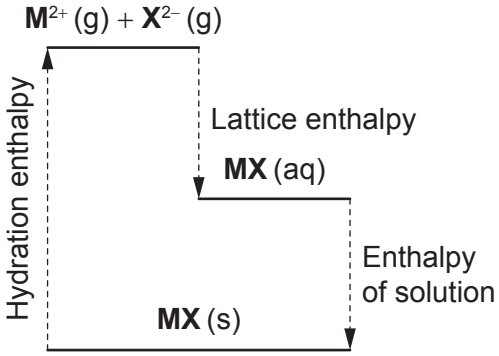
D. $+74 + 484 - 222$

15. Which allotrope, oxygen or ozone, has the stronger bond between O atoms, and which absorbs higher frequency UV radiation in the atmosphere?

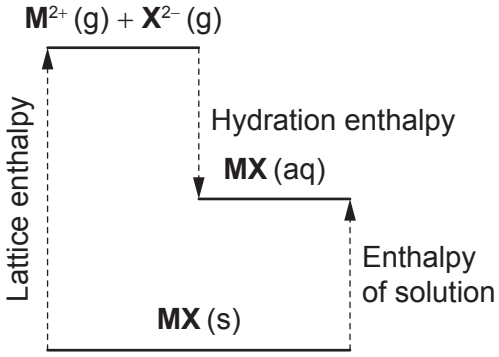
	Stronger bond between O atoms	Absorbs higher frequency UV
A.	ozone	ozone
B.	ozone	oxygen
C.	oxygen	oxygen
D.	oxygen	ozone

16. Which diagram shows the enthalpy changes for dissolving a solid, **MX**, in water, if the process increases the temperature of the solution?

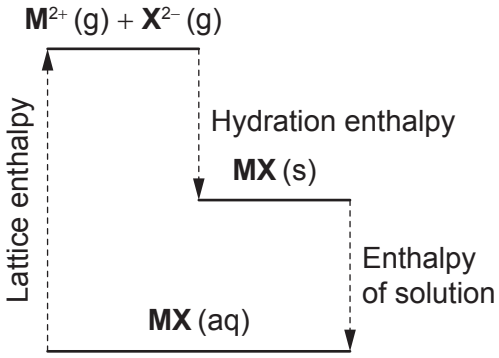
A.



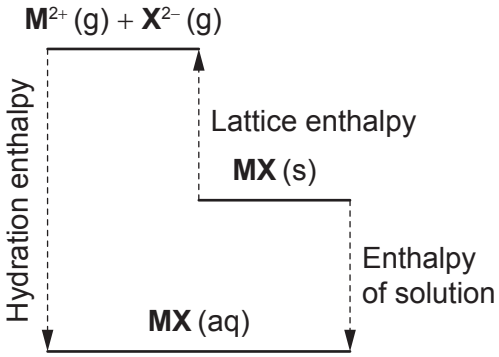
B.



C.



D.



17. What is the correct combination of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for a reaction which is only spontaneous at high temperature?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	+	+
B.	+	–
C.	–	+
D.	–	–

18. What happens to the average kinetic energy, KE, of the particles in a gas when the absolute temperature is doubled?

$$KE = \frac{1}{2} mv^2$$

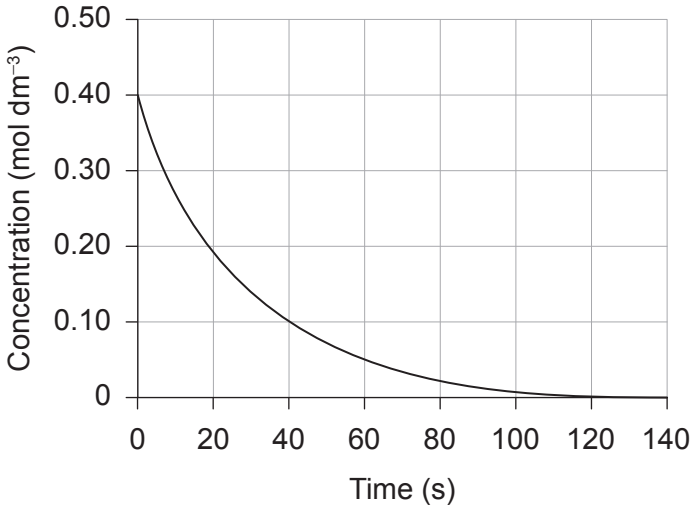
A. Increases by a factor of 2

B. Decreases by a factor of 2

C. Increases by a factor of 4

D. Decreases by a factor of 4

19. Which calculation determines the initial rate of this reaction?



A. $\frac{0.40 - 0.19}{20 - 0}$

B. $\frac{0.40 - 0.10}{40 - 0}$

C. $\frac{0.40 - 0}{140 - 0}$

D. $\frac{0.40 - 0.20}{10 - 0}$

20. What is the order of reaction with respect to A, given the following reaction mechanism?

$$A + B \rightarrow AB \qquad \textit{fast}$$

$$AB + A \rightarrow A_2B \qquad \textit{slow}$$

$$A_2B \rightarrow A_2 + B \qquad \textit{fast}$$

A. 0

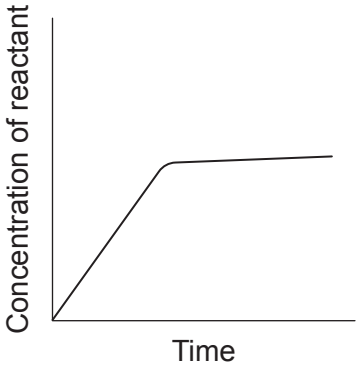
B. 1

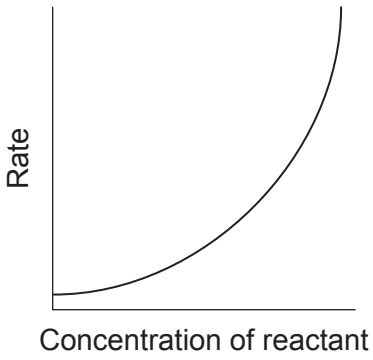
C. 2

D. 3

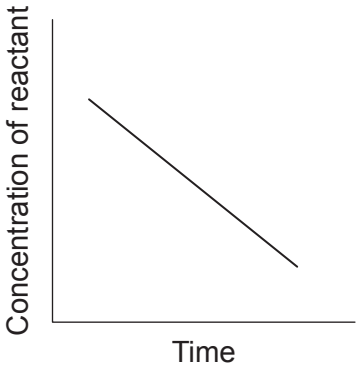
21. Which pair of graphs indicate the same order of reaction?

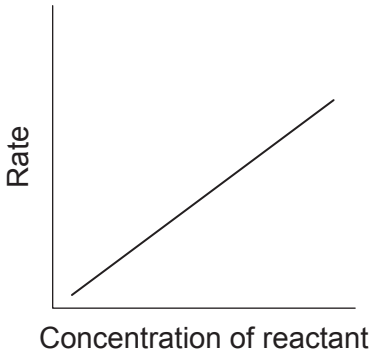
A.



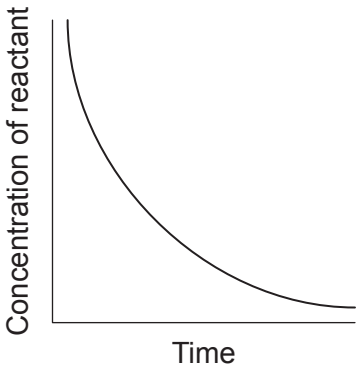


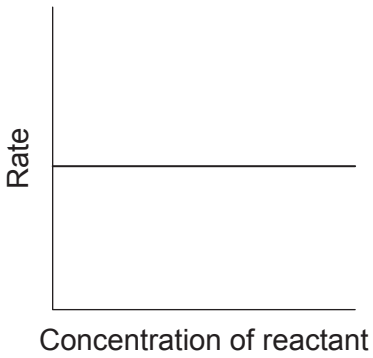
B.



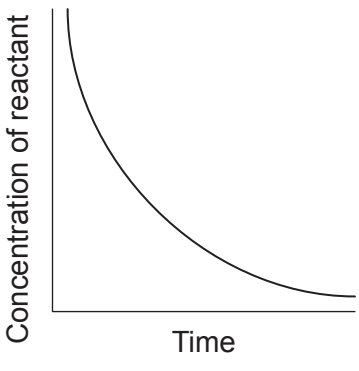


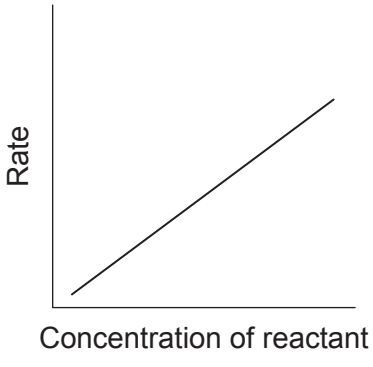
C.





D.





22. This reaction has an equilibrium constant $K_c = 650$ at a certain temperature.

$$NO_2(g) + SO_2(g) \rightleftharpoons NO + SO_3(g)$$

What is the equilibrium constant for the following reaction at the same temperature?

$$\frac{1}{2}\,NO(g) + \frac{1}{2}SO_3(g) \rightleftharpoons \frac{1}{2}NO_2(g) + \frac{1}{2}SO_2(g)$$

A. $\sqrt{650}$

B. $\frac{1}{650}$

C. $\frac{1}{\sqrt{650}}$

D. $\frac{1}{2} \times 650$

23. Which equilibrium constant corresponds to the spontaneous reaction with the most negative value of $\Delta G^{\ominus}$?

A. 4.9×10^{-3}

B. 8.2×10^{-3}

C. 4.9×10^{2}

D. 8.2×10^{2}

24. Which products are formed from the neutralization of nitric acid by calcium hydroxide?

A. Calcium oxide and ammonia

B. Calcium nitrate and water

C. Calcium nitrate and ammonia

D. Calcium nitrate and hydrogen

25. Which combination describes a strong Brønsted–Lowry acid?

	Proton donor	Conjugate base
A.	good	strong
B.	good	weak
C.	poor	strong
D.	poor	weak

26. What is the relationship between acid and base dissociation constants in a conjugate acid–base pair?

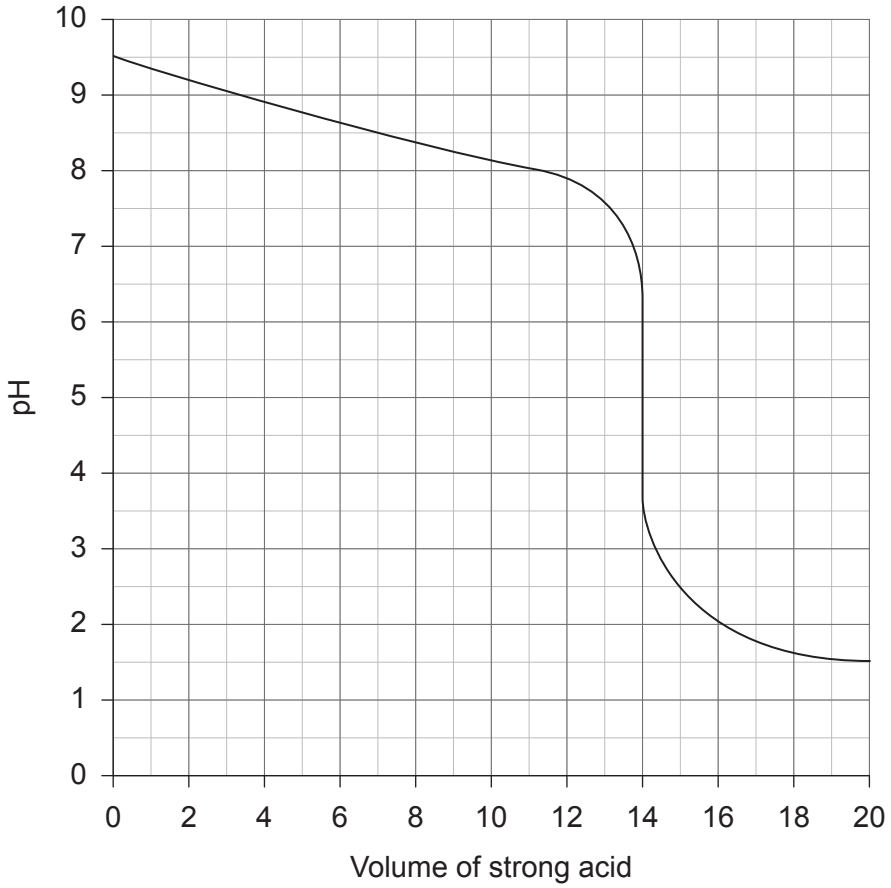
A. $K\text{a} \times K\text{b} = K\text{w}$

B. $\dfrac{K\text{a}}{K\text{b}} = K\text{w}$

C. $\text{p}K\text{a} \times \text{p}K\text{b} = \text{p}K\text{w}$

D. $\dfrac{\text{p}K\text{a}}{\text{p}K\text{b}} = \text{p}K\text{w}$

27. What is the pH at the equivalence point in this titration?



A. 8.5

B. 7.0

C. 5.0

D. 1.5

28. Which change involves oxidation of N?

A. NH_3 to N_2

B. NO_2 to NO

C. N_2 to AlN

D. NO_2 to N_2O_4

29. Which combination describes an electrolytic cell?

	Energy change	Spontaneity
A.	chemical to electrical	non-spontaneous
B.	electrical to chemical	non-spontaneous
C.	chemical to electrical	spontaneous
D.	electrical to chemical	spontaneous

30. What is the standard potential difference of this cell?

$$Fe(s) \mid Fe^{2+}(aq) \parallel Ag^{+}(aq) \mid Ag(s)$$

Reaction	$E^{\ominus}$
$Fe^{2+}(aq) + 2e^{-} \rightleftharpoons Fe(s)$	$-0.45\,V$
$Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$	$+0.80\,V$

A. $0.45 + 2(0.80)$

B. $0.45 + 0.80$

C. $-0.45 - 2(0.80)$

D. $-0.45 - 0.80$

31. Which statement is correct about the ions in a cell assembled from these half-cells?

Reaction	$E^{\ominus}$
$Ni^{2+}(aq) + 2e^{-} \rightleftharpoons Ni(s)$	$-0.26\,V$
$Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s)$	$-0.76\,V$

A. Negative ions flow into the zinc half-cell from the salt bridge.

B. Negative ions flow into the nickel half-cell from the salt bridge.

C. Zn^{2+} ions are reduced to Zn.

D. The concentration of Ni^{2+} ions increases.

32. Which formula represents an ether?

A. C_6H_5OH

B. CH_3CHO

C. CH_3COCH_3

D. CH_3OCH_3

33. Why does benzene undergo substitution more readily than addition?

A. Benzene is unsaturated.

B. Addition could produce an alkane.

C. Resonance makes carbon–carbon bonds too strong to break.

D. A benzene molecule is planar.

34. What is the product of the reaction of but-2-ene with bromine?

A. 1,2-dibromobutane

B. 2,2-dibromobutane

C. 2,3-dibromobutane

D. 3,3-dibromobutane

35. Which molecule is optically active?

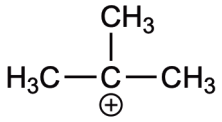
A. 2,2-dichloropropane

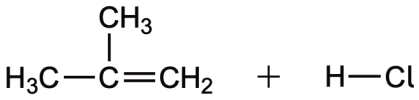
B. 1,2-dichloropropane

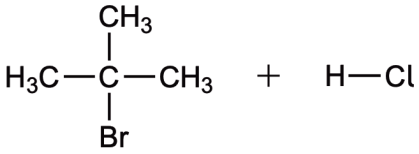
C. 1,3-dichloropropane

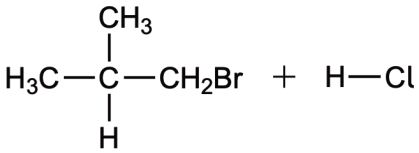
D. 1,2,3-trichloropropane

36. Which pairs of reactants could produce the following intermediate?



I. 

II. 

III. 

A. I and II only

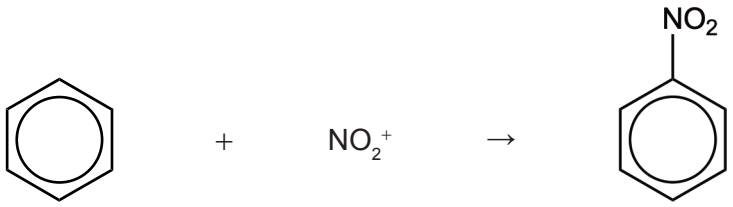
B. I and III only

C. II and III only

D. I, II and III

37. Which terms describe the nitronium ion in the nitration of benzene?

Benzene **Nitronium ion** **Nitrobenzene**



	Type of reactant	Acid-base nature
A.	nucleophile	Lewis base
B.	nucleophile	Lewis acid
C.	electrophile	Lewis base
D.	electrophile	Lewis acid

38. What is the percentage error if the enthalpy of combustion of a substance is determined experimentally to be –2100 kJ mol^{-1}, but the literature value is –3500 kJ mol^{-1}?

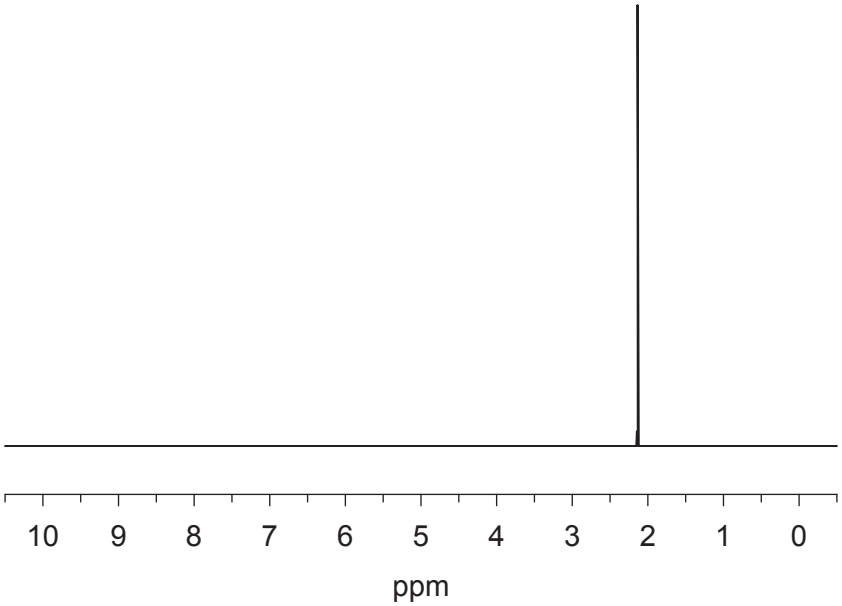
A. 80 %

B. 60 %

C. 40 %

D. 20 %

39. Which molecule produces this ^{1}H-NMR spectrum?



A. CH_3COOCH_3

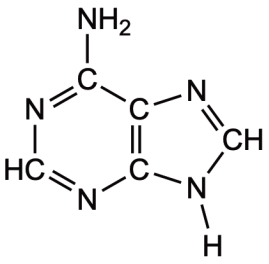
B. CH_3COCH_3

C. CH_3CHO

D. $CH_3CH_2CH_3$

40. What is the index of hydrogen deficiency of adenine?

Adenine ($C_5H_5N_5$)



A. 3

B. 4

C. 5

D. 6

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References:

39. SDBS, National Institute of Advanced Industrial Science and Technology.