Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

4 November 2024

Zone A afternoon | **Zone B** afternoon | **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]**.

8824 – 9540

20 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)

8824–9540

1. How many moles of phosphate ions, PO_4^{3-}, are there in 103.39 g of $Ca_3(PO_4)_2$?
$M_r = 310.18$

A. 0.11

B. 0.33

C. 0.67

D. 2.00

2. What is the sum of the coefficients for the balanced equation of the combustion of iron(II) sulphide using the smallest whole numbers?

$$\_FeS(s) + \_O_2(g) \rightarrow \_Fe_2O_3(s) + \_SO_2(g)$$

A. 6

B. 7

C. 14

D. 17

3. What is the yield of sodium chloride, in grams, when 4.60 g of sodium reacts with 1.14 dm^3 of chlorine gas at STP?
Molar volume = 22.7 $dm^3\,mol^{-1}$

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

A. 1.17

B. 2.92

C. 5.84

D. 11.7

4. What is the pressure, in Pa, inside a 3.0 dm^3 cylinder containing 64 g of O_2 at 25.0 °C?
R = 8.31 $J\,K^{-1}\,mol^{-1}$; $PV = nRT$

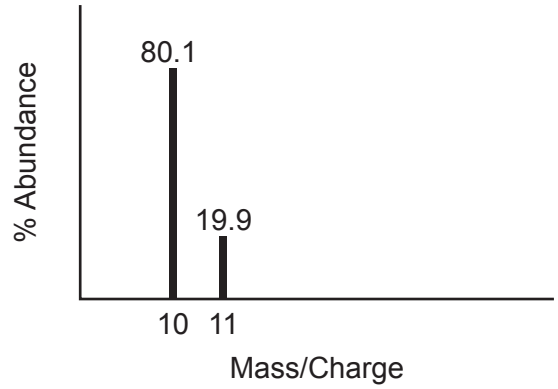
A. $\dfrac{2 \times 8.31 \times 25}{3.0}$

B. $\dfrac{2 \times 8.31 \times 298}{3.0 \times 10^{-3}}$

C. $\dfrac{2 \times 8.31 \times 298}{3.0}$

D. $\dfrac{4 \times 8.31 \times 298}{3.0 \times 10^{-3}}$

5. What is the A_r of the element as determined from its mass spectrum below?



A. 10.0

B. 10.2

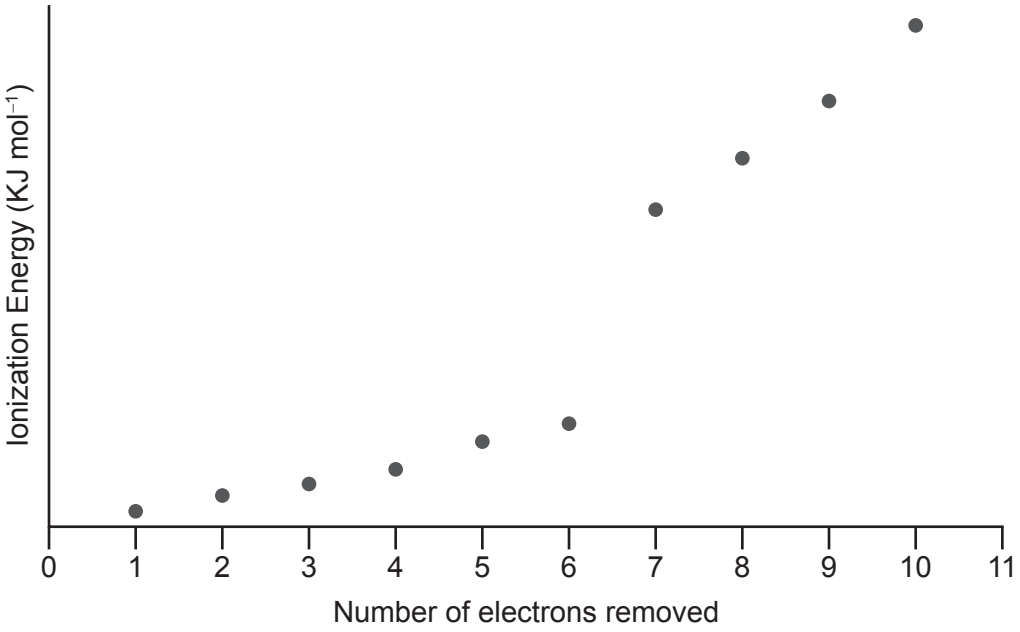
C. 10.5

D. 10.8

6. What is correct for the wavelength and energy of the radiation of the ultraviolet and visible regions of the electromagnetic spectrum?

	Ultraviolet region	**Visible region**
A.	Lower wavelength and higher energy	Higher wavelength and lower energy
B.	Lower wavelength and lower energy	Higher wavelength and higher energy
C.	Higher wavelength and lower energy	Lower wavelength and higher energy
D.	Higher wavelength and higher energy	Lower wavelength and lower energy

7. The graph represents the first ten ionization energies (IE) of an element.



What is the element?

A. Cl

B. Ne

C. O

D. S

8. $[Co(H_2O)_6]^{3+}$ is blue while $[Co(CN)_6]^{3-}$ is pale yellow. Which statement correctly explains the difference in colour?

A. The ligand in $[Co(CN)_6]^{3-}$ is weaker and absorbs light of higher frequency.

B. The oxidation state of cobalt is different in each complex.

C. The different colours are due to the different charges on the complex.

D. The ligand in $[Co(CN)_6]^{3-}$ causes larger 3*d* orbital splitting and absorbs light of higher frequency.

9. Which of these period 3 oxides forms a solution with pH<7 when added to water?

A. Al_2O_3

B. MgO

C. Na_2O

D. P_4O_6

10. Which configuration is that of a transition metal atom in its ground state?

A. $[Ne]3s^2 3p^6$

B. $[Ar]3d^9$

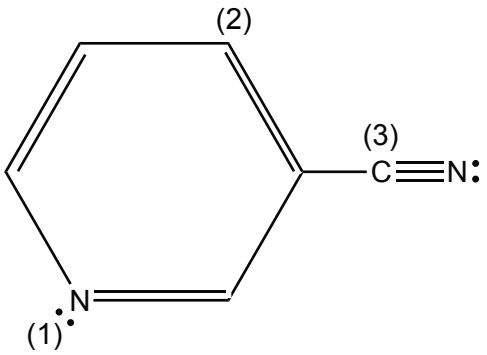
C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$

D. $[Ar]4s^1 3d^5$

11. Which types of intermolecular force exist between CH_4, CH_3OH and CH_3Cl molecules?

	CH_4	**CH_3OH**	**CH_3Cl**
A.	London dispersion only	London dispersion, H-bonding, dipole-dipole	London dispersion, dipole-dipole
B.	London dispersion, H-bonding	London dispersion, H-bonding, dipole-dipole	London dispersion, H-bonding, dipole-dipole
C.	London dispersion only	London dispersion, dipole-dipole	London dispersion only
D.	London dispersion, H-bonding	London dispersion only	London dispersion, dipole-dipole

12. What is the molecular geometry and hybridization of the numbered atoms in the molecule shown below?



	N(1)	C(2)	C(3)
A.	sp^2 / bent	sp^2 / trigonal planar	sp / linear
B.	sp^2 / trigonal planar	sp^2 / bent	sp^2 / bent
C.	sp^3 / tetrahedral	sp^2 / trigonal planar	sp / bent
D.	sp / bent	sp^3 / tetrahedral	sp^3 / linear

13. How many sigma (σ) and pi (π) bonds are present in the molecule below?

$(NC)_2CC(CN)_2$

	σ	π
A.	7	5
B.	9	5
C.	9	9
D.	13	5

14. Which statements are correct for alloys?

I. They are homogeneous mixtures of metals with other metals or non-metals.

II. The different sizes of atoms in alloys prevent layers of metallic cations sliding over each other easily.

III. Adding carbon to iron produces an alloy that is stronger than pure iron.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

15. What are the signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for this reaction that is non-spontaneous at high temperatures and spontaneous at low temperatures?
$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

$$SO_3(l) + CaO(s) \rightarrow CaSO_4(s)$$

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

16. Consider the following equations:

$$H_2(g) + F_2(g) \rightarrow 2HF(g) \qquad \Delta H^{\ominus} = -x\,kJ$$

$$C(s) + 2F_2(g) \rightarrow CF_4(g) \qquad \Delta H^{\ominus} = -y\,kJ$$

$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^{\ominus} = +z\,kJ$$

What is the $\Delta H^{\ominus}$ of the reaction?

$$C_2H_4(g) + 6F_2(g) \rightarrow 2CF_4(g) + 4HF(g)$$

A. $-x - y - z$

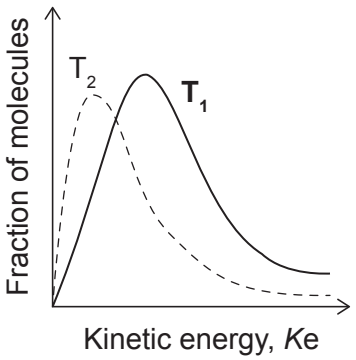
B. $-x - y + z$

C. $-2x + 2y - z$

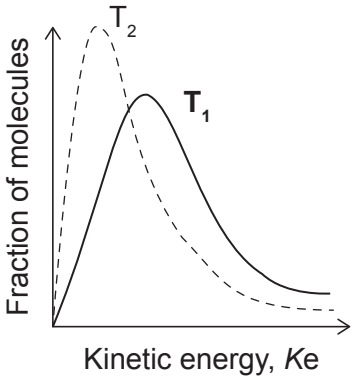
D. $-2x - 2y - z$

17. Which of the diagrams represents the Maxwell–Boltzmann distribution of kinetic energy of molecules of the same sample of a gas at two temperatures, T1 and T2, when T1>T2?

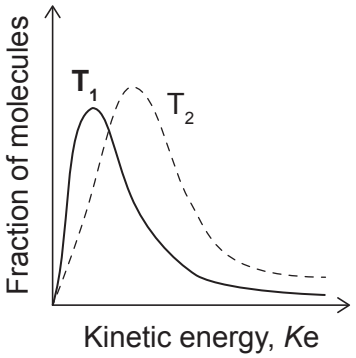
A.



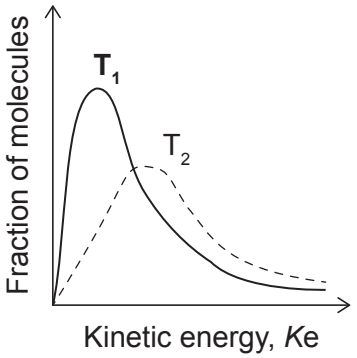
B.



C.



D.



18. What is the enthalpy change, in $kJ\,mol^{-1}$, when 107 g of solid ammonium chloride, NH_4Cl, are added to water to form 50.0 cm^3 of solution, producing a maximum decrease of 28 °C?
M_r $NH_4Cl = 53.5$
Specific heat capacity of water= $4.18\,J\,g^{-1}\,K^{-1}$

A. $\Delta H = \dfrac{-50.0 \times 4.18 \times (28 + 273)}{2 \times 1000}$

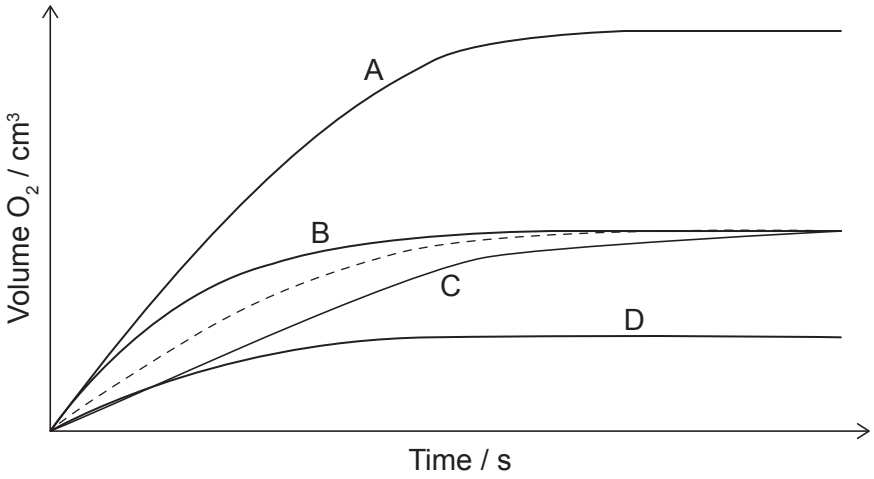
B. $\Delta H = \dfrac{-50.0 \times 4.18 \times 28}{2 \times 1000}$

C. $\Delta H = \dfrac{50.0 \times 4.18 \times (28 + 273)}{2 \times 1000}$

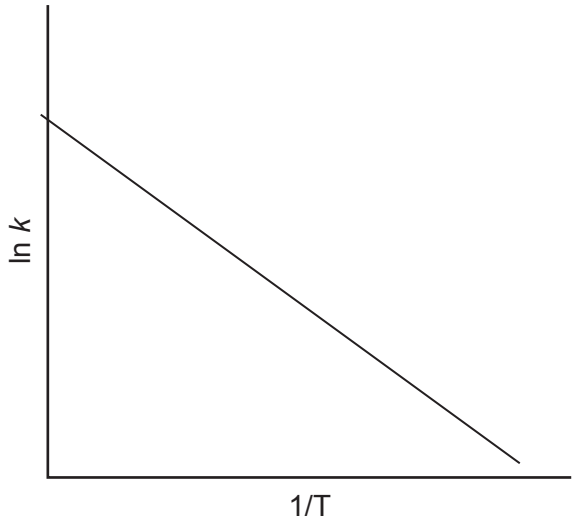
D. $\Delta H = \dfrac{50.0 \times 4.18 \times 28}{2 \times 1000}$

19. The non-catalysed decomposition of H_2O_2 was monitored giving the dotted line in the following graph.

Which curve represents the catalysed reaction if performed at the same temperature and using the same concentration of reactants?



20. The rate constants of a reaction at different temperatures were plotted giving the following graph.



What does the slope of the line represent?

$$\ln k = \frac{-E_a}{RT} + \ln A$$

A. $-E_a/R$

B. $-E_a$

C. $\ln A$

D. $-E_a/RT$

21. The reaction between carbon monoxide and nitrogen dioxide follows the two-step mechanism:

$2NO_2(g) \rightarrow NO_3(g) + NO(g)$ *Slow step*
$CO(g) + NO_3(g) \rightarrow CO_2(g) + NO_2(g)$ *Fast step*

What is the rate expression of this reaction?

A. Rate $= k[NO_2]^2$

B. Rate $= k[NO_2]^2[CO][NO_3]$

C. Rate $= k[CO][NO_3]$

D. Rate $= k[NO_2]^2[CO]$

22. Carbon dioxide dissolves in water as shown in the equation below. What will happen if the temperature of the aqueous solution is increased?

$$CO_2(g) + 2H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq) \qquad \Delta H^{\ominus} = -19.3\,kJ\,mol^{-1}$$

A. The equilibrium shifts to the right and pH decreases.

B. The equilibrium shifts to the right and pH increases.

C. The equilibrium shifts to the left and pH increases.

D. The equilibrium shifts to the left and pH decreases.

23. Which of the following statements is correct for the position of equilibrium of a reaction?

$$\Delta G^{\ominus} = -RT\ln K$$

I. It will always shift to the right when temperature increases.

II. If $\Delta G^{\ominus} < 0$, then $K > 1$ and products are favoured over reactants.

III. If $\Delta G^{\ominus} = 0$, then $K = 1$ and [reactants] and [products] are approximately equal.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

24. The pH of an aqueous solution **Z** is 5 and the pH of an aqueous solution **X** is 10. What is the ratio of their H_3O^+ concentrations?

A. $[H_3O^+]$ is 2 times lower in **X** than in **Z**.

B. $[H_3O^+]$ is 5 times lower in **X** than in **Z**.

C. $[H_3O^+]$ is 1×10^2 times lower in **X** than in **Z**.

D. $[H_3O^+]$ is 1×10^5 times lower in **X** than in **Z**.

25. Using the data provided in the table, which of the conjugate bases is the strongest?

Acid	K_a
HClO	2.9×10^{-8}
C_6H_5COOH	6.3×10^{-5}
H_3PO_4	7.3×10^{-3}
H_2SO_3	1.3×10^{-2}

A. ClO^-

B. $C_6H_5COO^-$

C. $H_2PO_4^-$

D. HSO_3^-

26. Consider the phosphate buffer system, Na_2HPO_4 /NaH_2PO_4.

What is correct when a small amount of a strong base is added to the buffer?

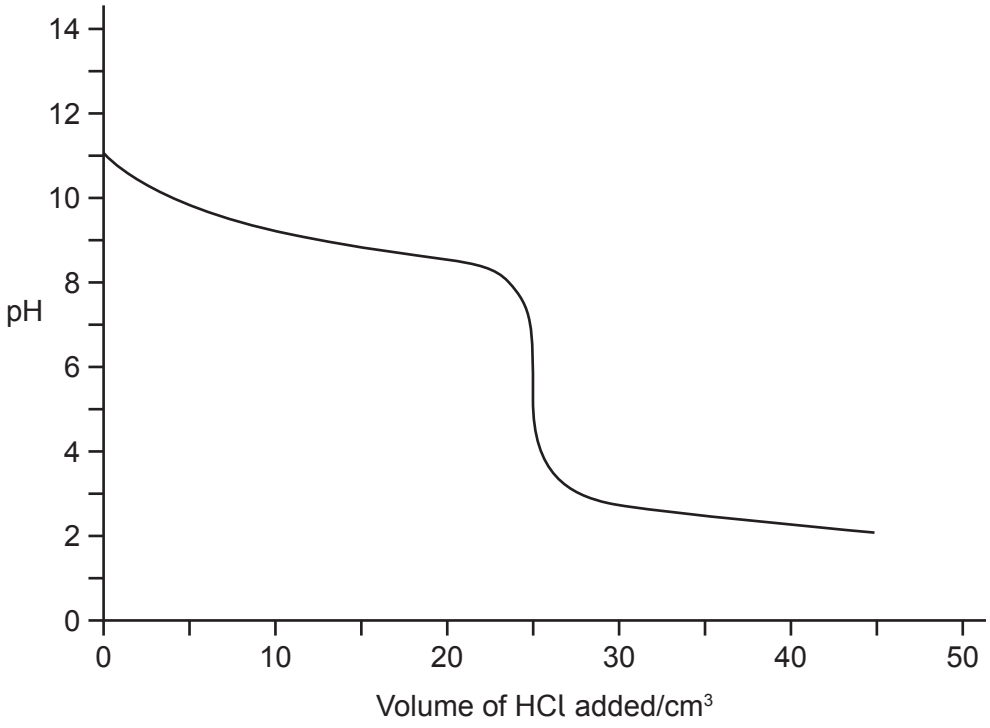
A. OH^- react with Na^+ to form NaOH.

B. $[H_2PO_4^-]$ increases.

C. $[HPO_4^{2-}]$ increases.

D. OH^- react with $H_2PO_4^-$ to form PO_4^{3-}.

27. A 25 cm^3 sample of a weak base was titrated with hydrochloric acid, HCl.



What is the pK_b of the base?

A. 2

B. 5

C. 9

D. 11

28. In which reaction does H_2 act as an oxidizing agent?

A. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

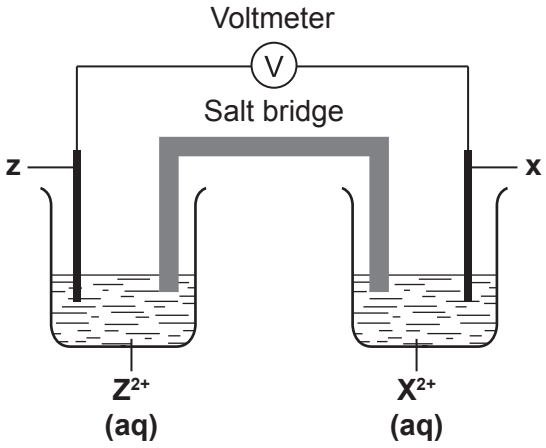
B. $2Na(s) + H_2(g) \rightarrow 2NaH(s)$

C. $Cl_2(g) + H_2(g) \rightarrow 2HCl(g)$

D. $H_2CCH_2(g) + H_2(g) \rightarrow H_3CCH_3(g)$

29. A voltaic cell is constructed from half-cells using metals **X** and **Z** as electrodes. What will occur when this cell produces electricity?

$\mathbf{X}^{2+}(aq) + 2e^- \rightleftharpoons \mathbf{X}(s)$ $E^{\ominus} = +0.25$ v
$\mathbf{Z}^{2+}(aq) + 2e^- \rightleftharpoons \mathbf{Z}(s)$ $E^{\ominus} = -0.60$ v



A. Positive ions flow through the salt bridge to **Z** half-cell.

B. Electrons flow from **X** half-cell to **Z** half-cell.

C. The concentration of $\mathbf{X}^{2+}$ increases.

D. Mass of electrode **Z** decreases.

30. Which statement is correct for a reaction in a voltaic cell, for which both $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ are positive?

$$\Delta G^{\ominus} = -nFE^{\ominus}$$

A. $E^{\ominus}$ cell will increase with an increase in temperature.

B. $E^{\ominus}$ cell will decrease with an increase in temperature.

C. $E^{\ominus}$ cell will not change when the temperature increases.

D. $\Delta G^{\ominus} > 0$ for all temperatures.

31. Which statement is correct for the value of $E^{\ominus}$ of the standard hydrogen electrode (SHE)?

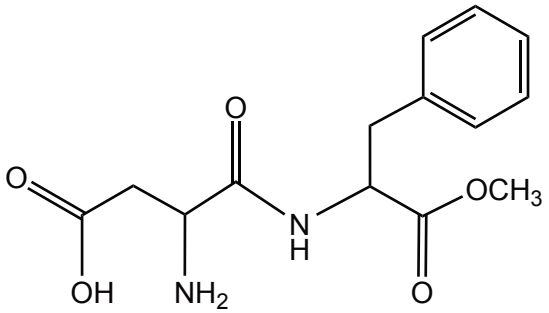
A. It was determined experimentally.

B. It depends on the temperature.

C. It was arbitrarily set.

D. It depends on the $E^{\ominus}$ of the second electrode.

32. Which of these functional groups are present in aspartame?



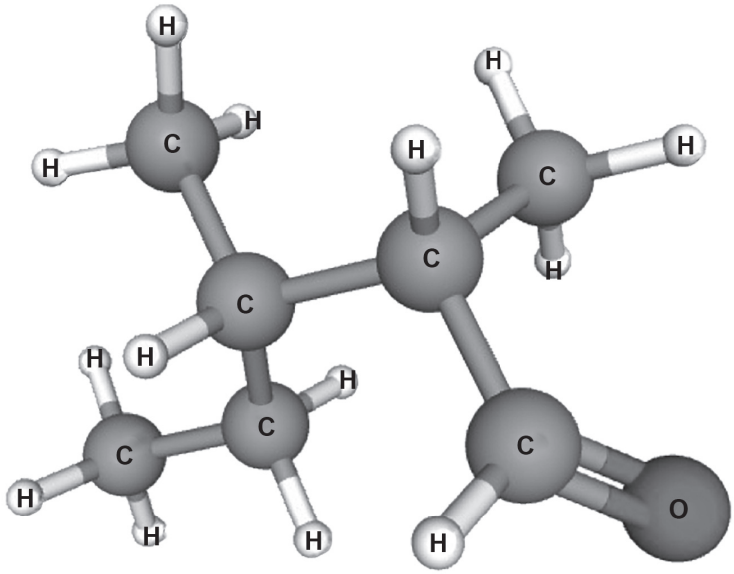
A. Carboxyl, secondary amino and ether

B. Carboxyl, secondary amino and ester

C. Ether, primary amino and secondary amino

D. Ester, primary amino and carboxyl

33. What is the IUPAC name of this compound?



A. 2,3-dimethylpentanal

B. 2,3-methylpentanal

C. 2-methyl-3-ethylbutanal

D. 3-ethyl-2-methylbutanal

34. Which of the following compounds can react with acidified potassium dichromate to give an acid?

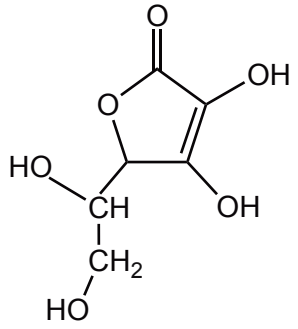
A. $CH_3CH(OH)CH_3$

B. CH_3COCH_3

C. $CH_3CH_2CH(CH_2OH)CH_2CH_3$

D. $CH_3C(CH_3)(OH)CH_3$

35. How many optical isomers exist for ascorbic acid?



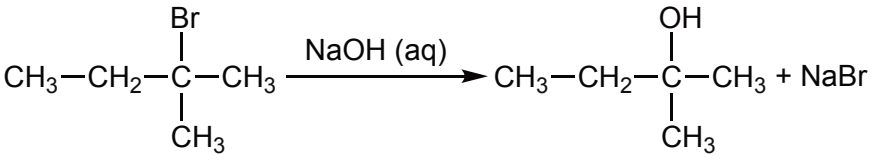
A. 2

B. 4

C. 5

D. 6

36. 2-bromo-2-methylbutane, $CH_3CH_2CBr(CH_3)_2$, reacts with a warm solution of NaOH to form an alcohol.



What is the reaction mechanism and rate expression?

	Reaction mechanism	Rate expression
A.	S_N2	$rate = k[CH_3CH_2CBr(CH_3)_2]\ [OH^-]$
B.	S_N1	$rate = k[CH_3CH_2CBr(CH_3)_2]$
C.	S_N1	$rate = k[CH_3CH_2CBr(CH_3)_2]\ [OH^-]$
D.	S_N2	$rate = k[CH_3CH_2CBr(CH_3)_2]$

37. Which of the following compounds would give an optically active compound on reacting with $LiAlH_4$?

A. Propanal

B. Butanal

C. Butanone

D. Propanone

38. Which statements are correct about the molecular ion, M^+, in a mass spectrum?

I. The M^+ is **not** always the peak with highest intensity in the mass spectrum.

II. The M^+ is always the most stable fragment formed during electron bombardment.

III. The *m/z* ratio of the M^+ ion peak gives the relative molecular mass of the molecule.

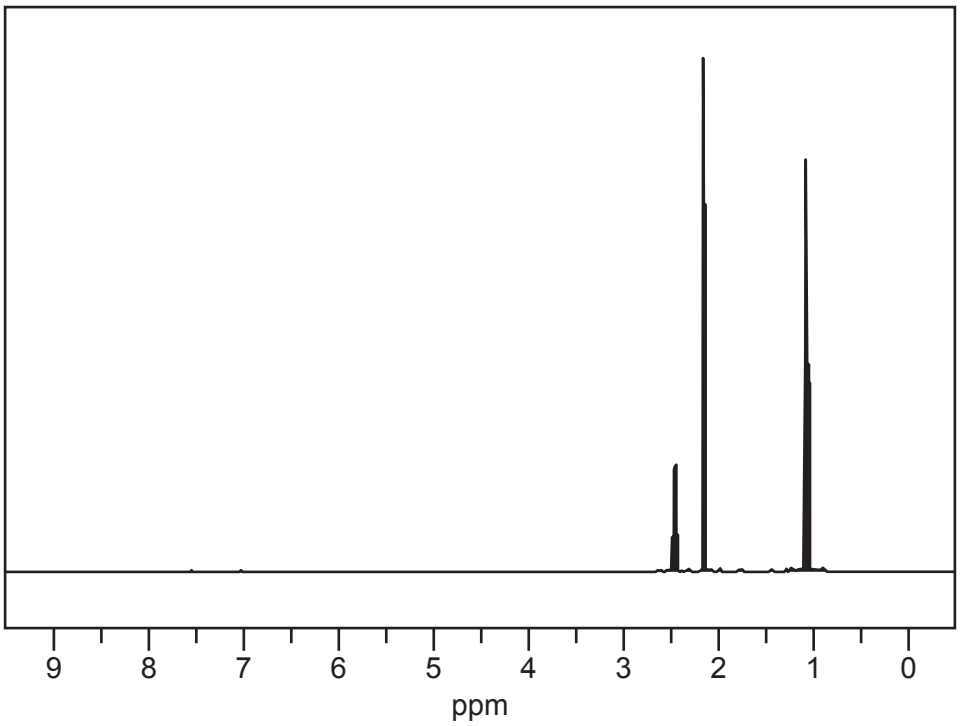
A. I and II only

B. I and III only

C. II and III only

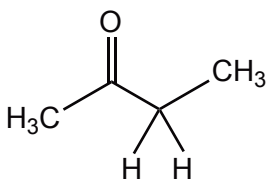
D. I, II and III

39. Which compound gives this ^{1}HNMR spectrum?

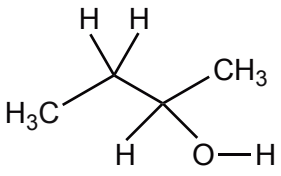


[Source: SDBS, National Institute of Advanced Industrial Science and Technology.]

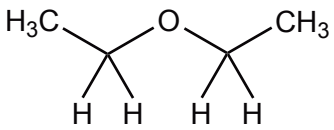
A.



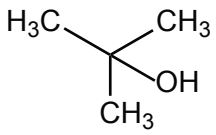
B.



C.



D.



40. A student performs an investigation to determine the content of ethanoic acid in vinegar samples using a non-standardized sodium hydroxide solution. Which type of error will occur and how will this affect the quality of the data obtained?

A. Systematic error and lower accuracy

B. Systematic error and lower precision

C. Random error and lower precision

D. Random error and lower accuracy

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References:

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