



Diploma Programme
Programme du diplôme
Programa del Diploma

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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]**.

20 pages

8824–9540
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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	3 Li 6.94	4 Be 9.01																
3	11 Na 22.99	12 Mg 24.31																
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 50.94	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 Nb 91.22	41 Zr 92.91	42 Tc (98)	43 Mo 95.96	44 Ru (98)	45 Rh 101.07	46 Pd 102.91	47 Ag 106.42	48 Cd 107.87	49 In 112.41	50 Sn 114.82	51 Sb 118.71	52 Te 121.76	53 I 127.60	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 Uut (286)	114 Uug (288)	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. How many moles of phosphate ions, PO_4^{3-} , are there in 103.39 g of $\text{Ca}_3(\text{PO}_4)_2$?
 $M_r = 310.18$

- A. 0.11
- B. 0.33
- C. 0.67
- D. 2.00

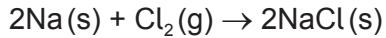
2. What is the sum of the coefficients for the balanced equation of the combustion of iron(II) sulphide using the smallest whole numbers?



- 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 dm³ of chlorine gas at STP?

Molar volume = 22.7 dm³ mol⁻¹



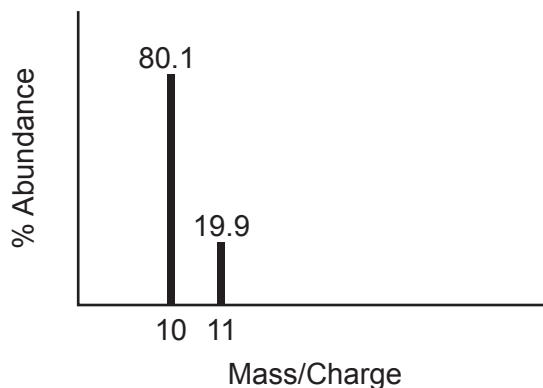
- A. 1.17
- B. 2.92
- C. 5.84
- D. 11.7

4. What is the pressure, in Pa, inside a 3.0 dm³ cylinder containing 64 g of O₂ at 25.0 °C?

$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$; $PV = nRT$

- A.
$$\frac{2 \times 8.31 \times 25}{3.0}$$
- B.
$$\frac{2 \times 8.31 \times 298}{3.0 \times 10^{-3}}$$
- C.
$$\frac{2 \times 8.31 \times 298}{3.0}$$
- D.
$$\frac{4 \times 8.31 \times 298}{3.0 \times 10^{-3}}$$

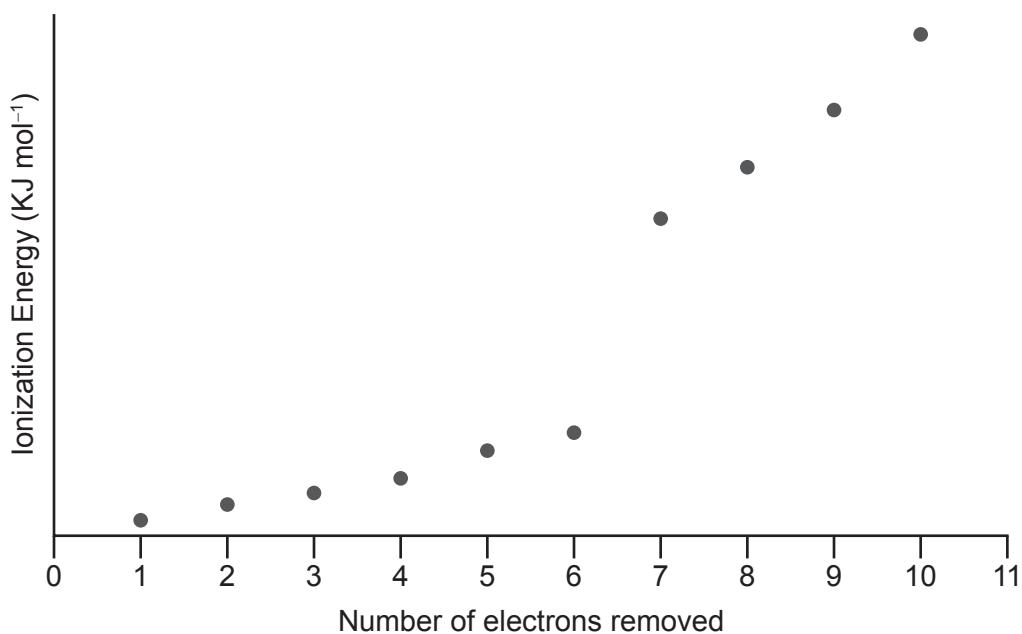
5. What is the A_r of the element as determined from its mass spectrum below?



- 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. $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ is blue while $[\text{Co}(\text{CN})_6]^{3-}$ is pale yellow. Which statement correctly explains the difference in colour?
- A. The ligand in $[\text{Co}(\text{CN})_6]^{3-}$ 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 $[\text{Co}(\text{CN})_6]^{3-}$ causes larger $3d$ 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

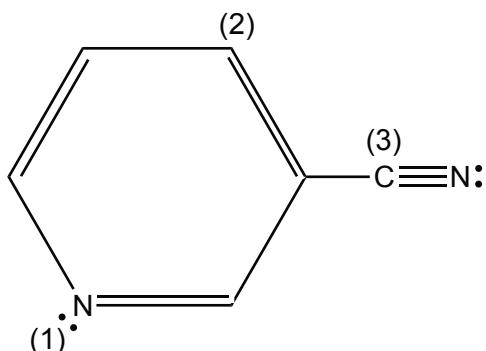
10. Which configuration is that of a transition metal atom in its ground state?

- A. $[\text{Ne}]3s^23p^6$
- B. $[\text{Ar}]3d^9$
- C. $1s^22s^22p^63s^23p^64s^23d^{10}4p^2$
- D. $[\text{Ar}]4s^13d^5$

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?



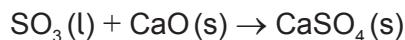
	σ	π
A.	7	5
B.	9	5
C.	9	9
D.	13	5

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

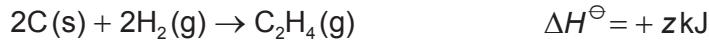
15. What are the signs of ΔH^\ominus and ΔS^\ominus for this reaction that is non-spontaneous at high temperatures and spontaneous at low temperatures?

$$\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$$

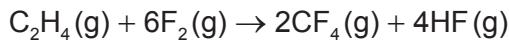


	ΔH^\ominus	ΔS^\ominus
A.	+	+
B.	-	-
C.	-	+
D.	+	-

16. Consider the following equations:



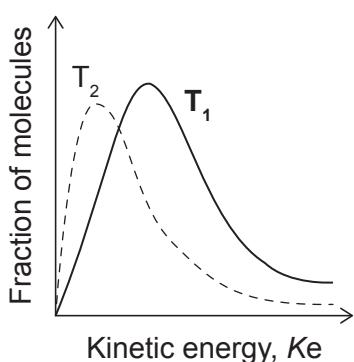
What is the ΔH^\ominus of the reaction?



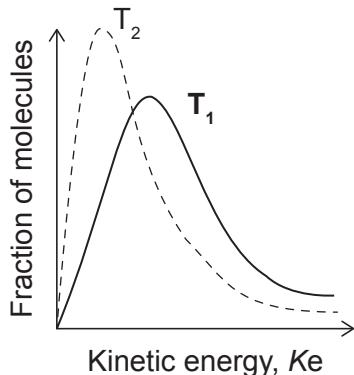
- A. $-x - y - z$
 B. $-x - y + z$
 C. $-2x + 2y - z$
 D. $-2x - 2y - z$

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?

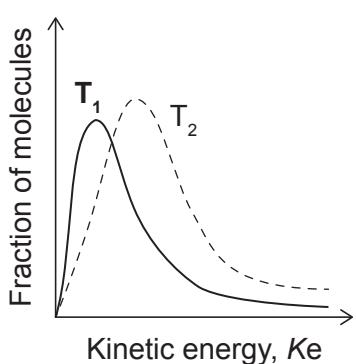
A.



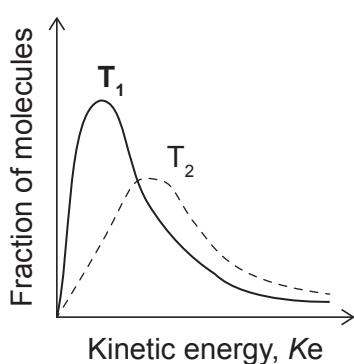
B.



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?

$$M_r \text{ NH}_4\text{Cl} = 53.5$$

$$\text{Specific heat capacity of water} = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$$

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

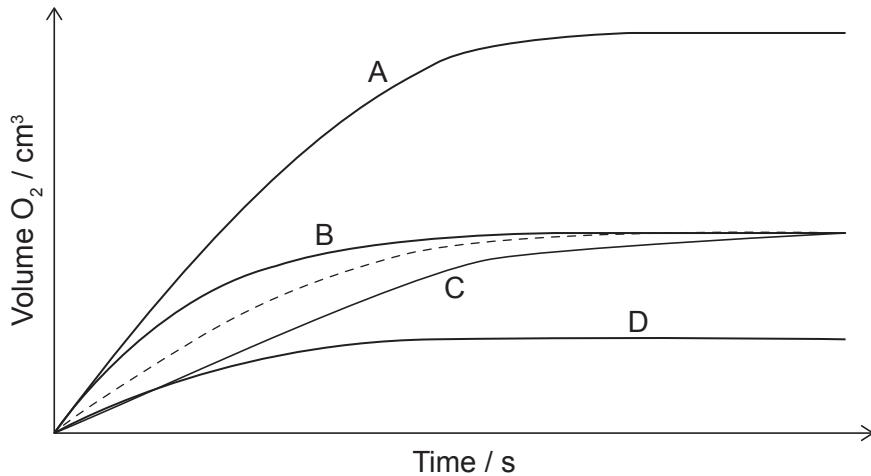
B. $\Delta H = \frac{-50.0 \times 4.18 \times 28}{2 \times 1000}$

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

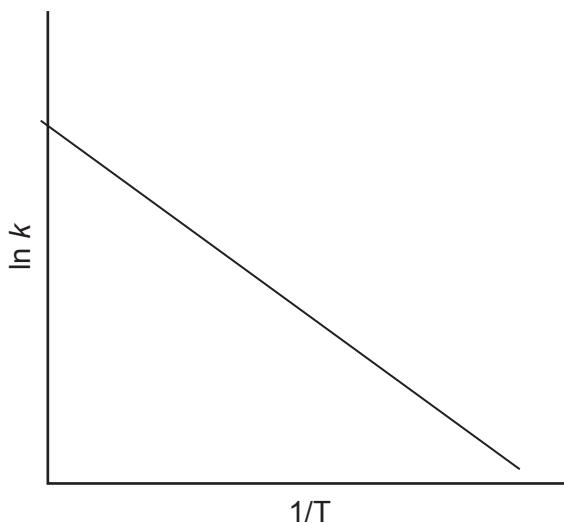
D. $\Delta H = \frac{50.0 \times 4.18 \times 28}{2 \times 1000}$

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.

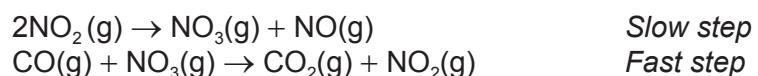


What does the slope of the line represent?

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

- 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:



What is the rate expression of this reaction?

- A. Rate = $k[\text{NO}_2]^2$
- B. Rate = $k[\text{NO}_2]^2[\text{CO}][\text{NO}_3]$
- C. Rate = $k[\text{CO}][\text{NO}_3]$
- D. Rate = $k[\text{NO}_2]^2[\text{CO}]$

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



- 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. $[\text{H}_3\text{O}^+]$ is 2 times lower in **X** than in **Z**.
 - B. $[\text{H}_3\text{O}^+]$ is 5 times lower in **X** than in **Z**.
 - C. $[\text{H}_3\text{O}^+]$ is 1×10^2 times lower in **X** than in **Z**.
 - D. $[\text{H}_3\text{O}^+]$ 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?

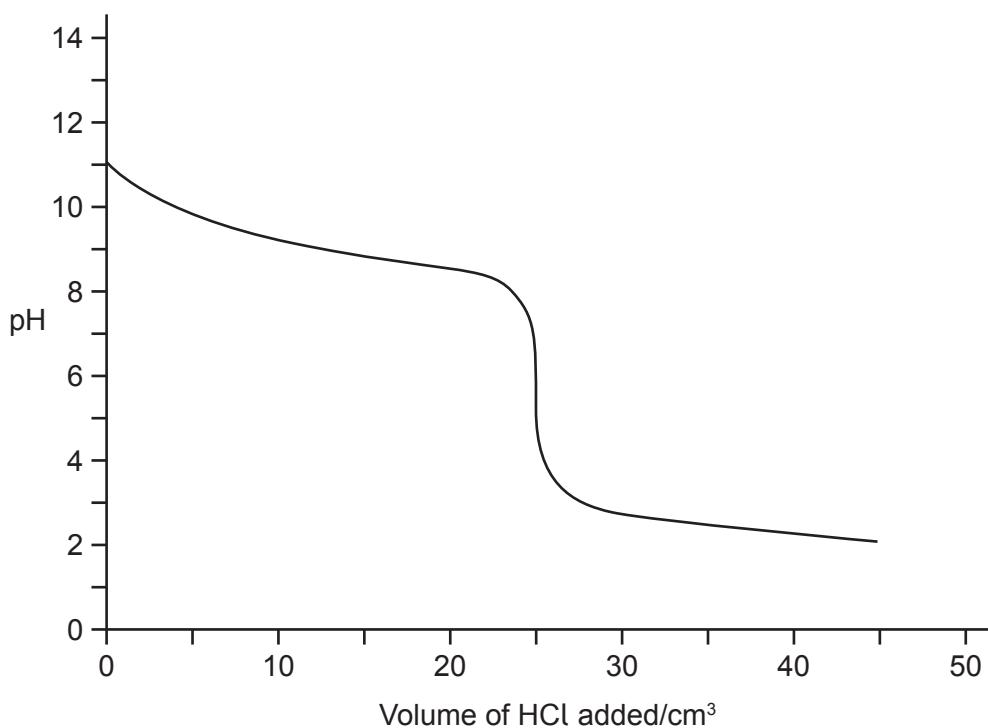
Acid	K_a
HClO	2.9×10^{-8}
C ₆ H ₅ COOH	6.3×10^{-5}
H ₃ PO ₄	7.3×10^{-3}
H ₂ SO ₃	1.3×10^{-2}

- A. ClO⁻
 B. C₆H₅COO⁻
 C. H₂PO₄⁻
 D. HSO₃⁻
- 26.** Consider the phosphate buffer system, Na₂HPO₄ /NaH₂PO₄.

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. [H₂PO₄⁻] increases.
 C. [HPO₄²⁻] increases.
 D. OH⁻ react with H₂PO₄⁻ to form PO₄³⁻.

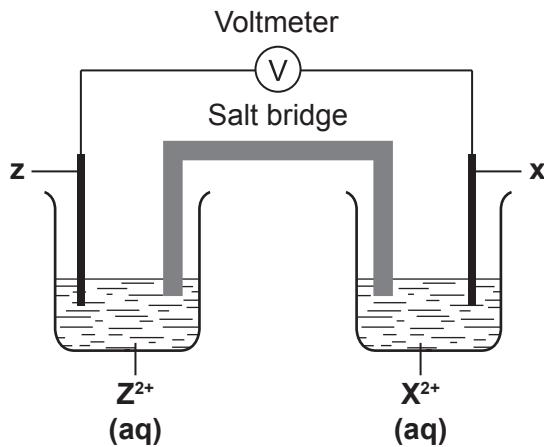
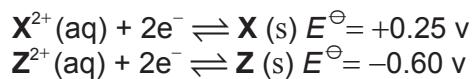
27. A 25 cm^3 sample of a weak base was titrated with hydrochloric acid, HCl.



What is the $\text{p}K_b$ of the base?

- A. 2
B. 5
C. 9
D. 11
28. In which reaction does H_2 act as an oxidizing agent?
- A. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$
B. $2\text{Na}(\text{s}) + \text{H}_2(\text{g}) \rightarrow 2\text{NaH}(\text{s})$
C. $\text{Cl}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})$
D. $\text{H}_2\text{CCH}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{H}_3\text{CCH}_3(\text{g})$

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



- 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 **X**²⁺ increases.
 - D. Mass of electrode **Z** decreases.
30. Which statement is correct for a reaction in a voltaic cell, for which both ΔH^\ominus and ΔS^\ominus are positive?

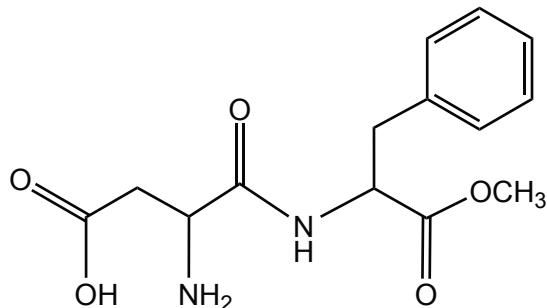
$$\Delta G^\ominus = -nFE^\ominus$$

- 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)?

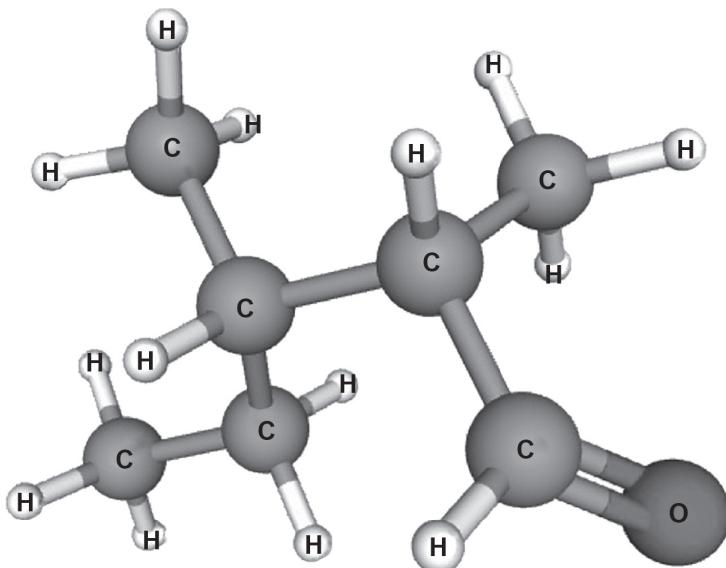
- A. It was determined experimentally.
- B. It depends on the temperature.
- C. It was arbitrarily set.
- D. It depends on the E^\ominus of the second electrode.

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



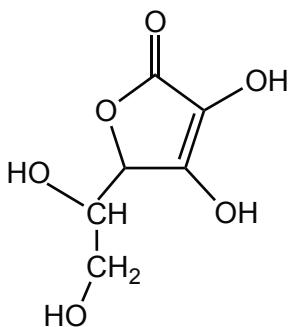
- A. Carboxyl, secondary amino and ether
- B. Carboxyl, secondary amino and ester
- C. Ether, primary amino and secondary amino
- D. Ester, primary amino and carboxyl

33. What is the IUPAC name of this compound?

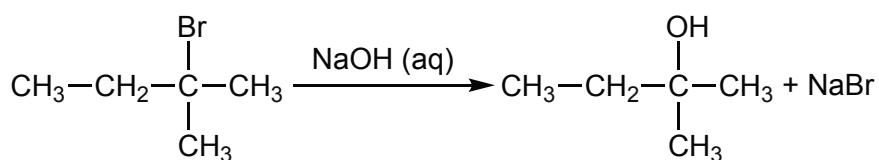


- A. 2,3-dimethylpentanal
 - B. 2,3-methylpentanal
 - C. 2-methyl-3-ethylbutanal
 - D. 3-ethyl-2-methylbutanal
34. Which of the following compounds can react with acidified potassium dichromate to give an acid?
- A. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
 - B. CH_3COCH_3
 - C. $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_2\text{OH})\text{CH}_2\text{CH}_3$
 - D. $\text{CH}_3\text{C}(\text{CH}_3)(\text{OH})\text{CH}_3$

35. How many optical isomers exist for ascorbic acid?



- A. 2
 B. 4
 C. 5
 D. 6
36. 2-bromo-2-methylbutane, $\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2$, 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 _N 2	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2] [\text{OH}^-]$
B.	S _N 1	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2]$
C.	S _N 1	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2] [\text{OH}^-]$
D.	S _N 2	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2]$

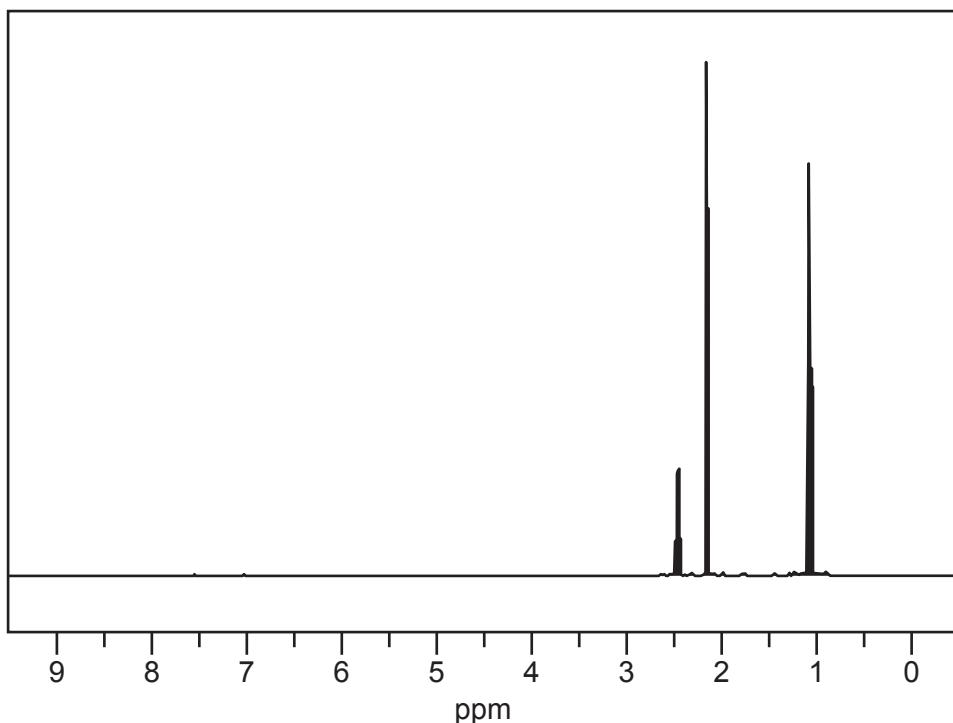
37. Which of the following compounds would give an optically active compound on reacting with LiAlH_4 ?

- A. Propanal
- B. Butanal
- C. Butanone
- D. Propanone

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

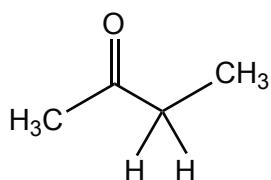
- I. The M^+ is **not** always the peak with highest intensity in the mass spectrum.
 - II. The M^+ is always the most stable fragment formed during electron bombardment.
 - III. The m/z ratio of the M^+ ion peak gives the relative molecular mass of the molecule.
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

39. Which compound gives this ^1H NMR spectrum?

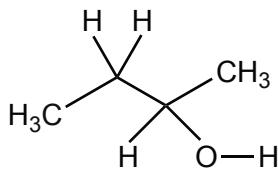


[Source: SDBS, National Institute of Advanced Industrial Science and Technology.]

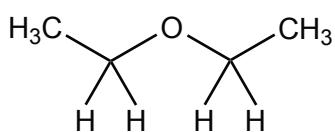
A.



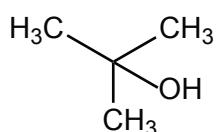
B.



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.

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