Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Wednesday 18 May 2022 (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]**.

2222 – 6113

16 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			Atomic number **Element** Relative atomic mass														2 **He** 4.00
2	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
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. What is the concentration of chloride ions, in $mol\,dm^{-3}$, in a solution formed by mixing $200\,cm^3$ of $1\,mol\,dm^{-3}$ HCl with $200\,cm^3$ of $5\,mol\,dm^{-3}$ NaCl?

A. 1

B. 2

C. 3

D. 6

2. 30 g of an organic compound produces 44 g CO_2 and 18 g H_2O as the only combustion products. Which of the following is the empirical formula for this compound?

$$M_r\ CO_2 = 44\ M_r\ H_2O = 18$$

A. CH_2

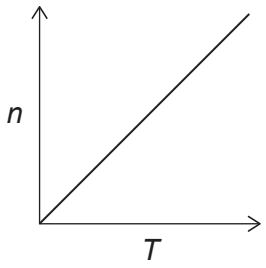
B. CH_3

C. CHO

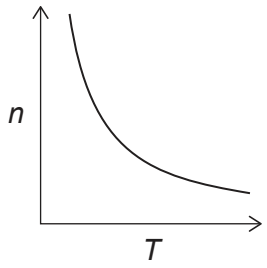
D. CH_2O

3. Which graph represents the relationship between the amount of gas, n, and the absolute temperature, T, with all other variables in the ideal gas equation, $PV = nRT$, held constant?

A.



B.



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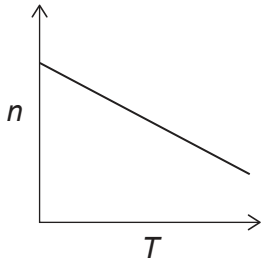
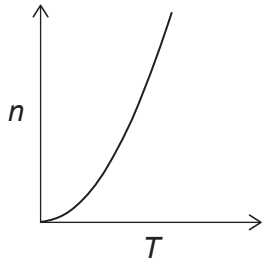
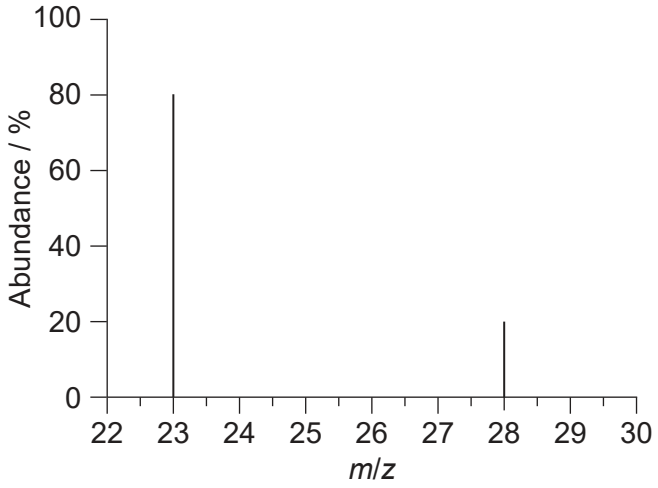


D.



4. What is the relative atomic mass of an element with the following mass spectrum?



A. 23

B. 24

C. 25

D. 28

5. What is the correct order for **increasing** first ionization energy?

A. Na < Mg < Al

B. Na < Al < Mg

C. Al < Mg < Na

D. Al < Na < Mg

6. Which are the most reactive elements of the alkali metals and halogens?

A. Lithium and fluorine

B. Lithium and iodine

C. Caesium and fluorine

D. Caesium and iodine

7. Which of these ions are likely to be paramagnetic?

I. Ti^{3+}

II. Cr^{3+}

III. Fe^{3+}

A. I and II only

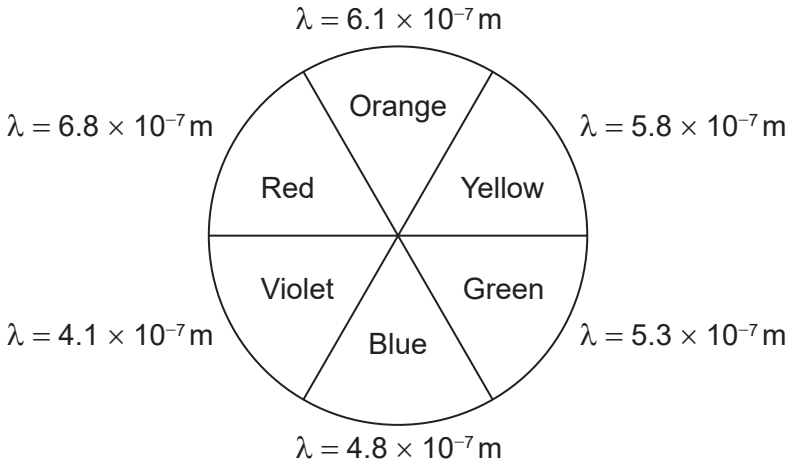
B. I and III only

C. II and III only

D. I, II and III

8. $[Cr(OH_2)_6]^{3+}$ is violet and $[Cr(NH_3)_6]^{3+}$ is yellow. What is correct?

The Colour Wheel



	Wavelength of light absorbed by $[Cr(OH_2)_6]^{3+}$	**d-level splitting caused by H_2O compared to NH_3 ligands**
A.	$\lambda = 5.8 \times 10^{-7}$ m	$H_2O > NH_3$
B.	$\lambda = 5.8 \times 10^{-7}$ m	$H_2O < NH_3$
C.	$\lambda = 4.1 \times 10^{-7}$ m	$H_2O > NH_3$
D.	$\lambda = 4.1 \times 10^{-7}$ m	$H_2O < NH_3$

9. In which of the following compounds does ionic bonding predominate?

A. HCl

B. NaF

C. NH_4Br

D. NaOH

10. What is the main interaction between liquid CH_4 molecules?

A. London (dispersion) forces

B. Dipole–dipole forces

C. Hydrogen bonding

D. Covalent bonding

11. What is the formal charge of the oxygen atom in H_3O^+?

A. –2

B. –1

C. 0

D. +1

12. What is the molecular geometry of SF_4?

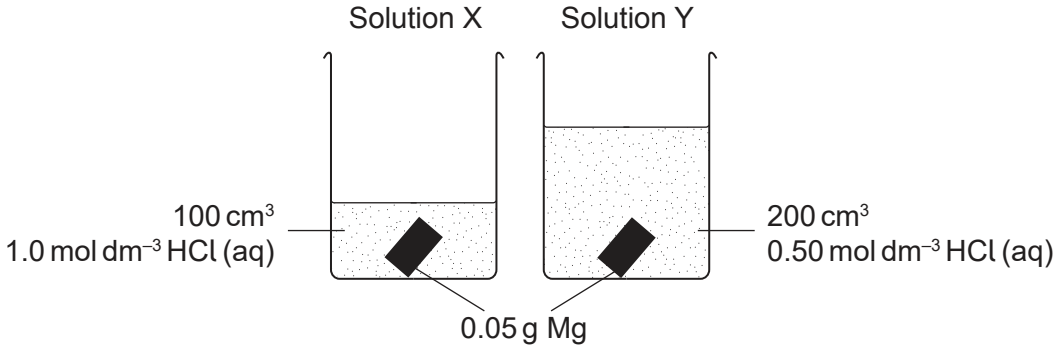
A. Tetrahedral

B. Trigonal bipyramidal

C. See-saw

D. Square planar

13. Which statement is correct about identical pieces of magnesium added to two solutions, X and Y, containing hydrochloric acid at the same temperature?



A. Solution X will reach a higher maximum temperature.

B. Solution Y will reach a higher maximum temperature.

C. Solutions X and Y will have the same temperature rise.

D. It is not possible to predict whether X or Y will have the higher maximum temperature because we cannot identify the limiting reactant.

14. Which equation represents hydration enthalpy?

A. $Na^+(g) \rightarrow Na^+(aq)$

B. $Na^+(aq) \rightarrow Na^+(g)$

C. $NaCl(s) \rightarrow NaCl(aq)$

D. $NaCl(aq) \rightarrow NaCl(s)$

15. What are the signs of ΔH and ΔS for a reaction that is non-spontaneous at low temperatures but spontaneous at high temperatures?

	ΔH	**ΔS**
A.	–	–
B.	–	+
C.	+	–
D.	+	+

16. Which equation represents the bond enthalpy for H–Br in hydrogen bromide?

A. $HBr(g) \rightarrow H^{+}(g) + Br^{-}(g)$

B. $HBr(g) \rightarrow H(g) + Br(g)$

C. $HBr(g) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}Br_2(l)$

D. $HBr(g) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}Br_2(g)$

17. Which term in the expression $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ is an indirect measure of the entropy change of the surroundings when divided by T?

A. $\Delta G^{\ominus}$

B. $\Delta H^{\ominus}$

C. $\Delta S^{\ominus}$

D. $- T\Delta S^{\ominus}$

18. Why does a reaction for a sample of gases, at constant temperature, occur faster at higher pressure?

A. Collisions are more frequent.

B. Collisions are more energetic.

C. High pressure lowers activation energy.

D. The reaction is more exothermic at high pressure.

19. What is correct about the rate of disappearance of NO?

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

$$\text{rate} = k[H_2][NO]^2$$

A. It equals half the rate of disappearance of H_2.

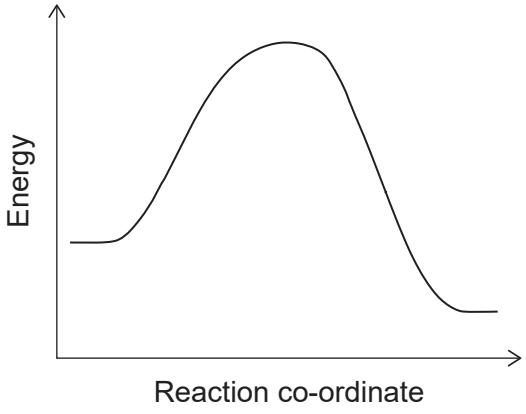
B. It equals the rate of disappearance of H_2.

C. It equals twice the rate of disappearance of H_2.

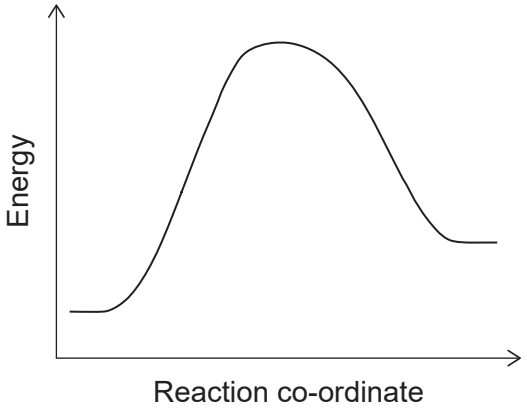
D. It equals four times the rate of disappearance of H_2.

20. Which energy profile diagram represents an exothermic S_N1 reaction?

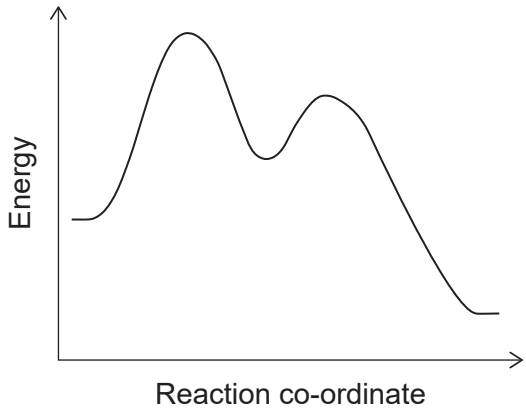
A.



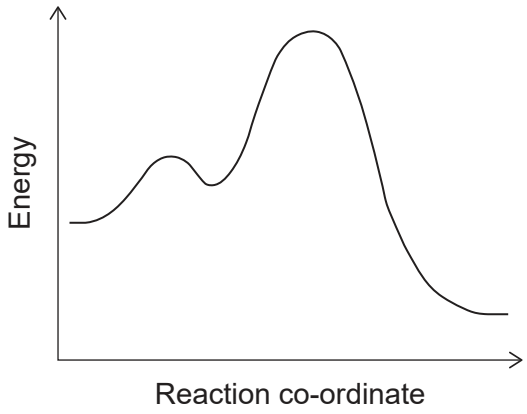
B.



C.



D.



21. Which factor influences the value of the pre-exponential factor, A, in the Arrhenius equation, $k = Ae^{-\frac{Ea}{RT}}$?

A. Nature of reactants

B. Temperature of reaction

C. Activation energy of reaction

D. Overall order of the reaction

22. The equilibrium constant, K_c, for the reaction $2A + 4B \rightleftharpoons 2C + 4D$ has a value of 4.0.
What is the value of K_c for the reaction below at the same temperature?

$$C + 2D \rightleftharpoons A + 2B$$

A. 0.25

B. 0.50

C. 1.0

D. 16

23. 0.50 mol of $I_2(g)$ and 0.50 mol of $Br_2(g)$ are placed in a closed flask. The following equilibrium is established.

$$I_2(g) + Br_2(g) \rightleftharpoons 2IBr(g)$$

The equilibrium mixture contains 0.80 mol of $IBr(g)$. What is the value of K_c?

A. 0.64

B. 1.3

C. 2.6

D. 64

24. What happens to the amount of hydroxide ions and hydroxide ion concentration when water is added to a solution of $NH_3(aq)$?

	***n*(OH⁻)**	**[OH⁻]**
A.	Increases	Increases
B.	Decreases	Decreases
C.	Increases	Decreases
D.	Decreases	Increases

25. What is the strongest acid in the equation below?

$$H_3AsO_4 + H_2O \rightleftharpoons H_2AsO_4^- + H_3O^+ \qquad K_c = 4.5 \times 10^{-4}$$

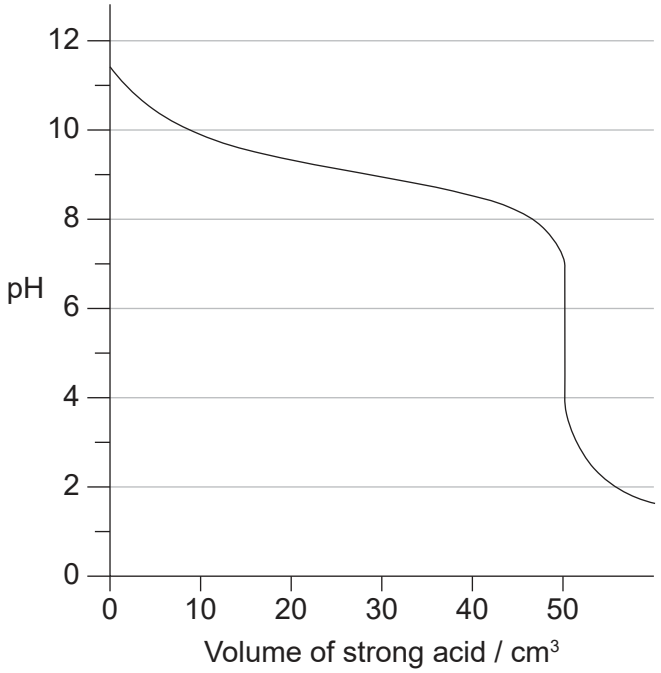
A. H_3AsO_4

B. H_2O

C. $H_2AsO_4^-$

D. H_3O^+

26. A weak base is titrated with a strong acid. Which value of pK_b can be estimated from this titration curve?



A. 11.3

B. 9.2

C. 4.8

D. 1.8

27. Which species are **both** Lewis and Brønsted–Lowry bases?

I. CN^-

II. OH^-

III. NH_3

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

28. Which combination best describes what is happening to chloromethane, CH_3Cl, in the equation below?

$$CH_3Cl(g) + H_2(g) \rightleftharpoons CH_4(g) + HCl(g)$$

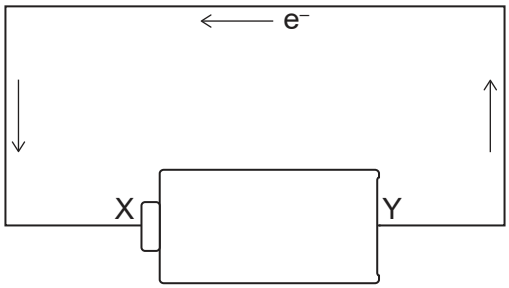
A. Oxidation and addition

B. Oxidation and substitution

C. Reduction and addition

D. Reduction and substitution

29. The arrows represent electron flow in the diagram. What does terminal X on the battery represent?



A. Anode and positive terminal

B. Anode and negative terminal

C. Cathode and positive terminal

D. Cathode and negative terminal

30. Which $E^{\ominus}$ value, in V, for the reaction $Mn(s) + Zn^{2+}(aq) \rightarrow Mn^{2+}(aq) + Zn(s)$ can be deduced from the following equations?

$$Mn(s) + 2Ag^{+}(aq) \rightarrow Mn^{2+}(aq) + 2Ag(s) \qquad E^{\ominus} = 1.98\,V$$

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s) \qquad E^{\ominus} = 1.10\,V$$

$$Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s) \qquad E^{\ominus} = 0.46\,V$$

A. 0.42

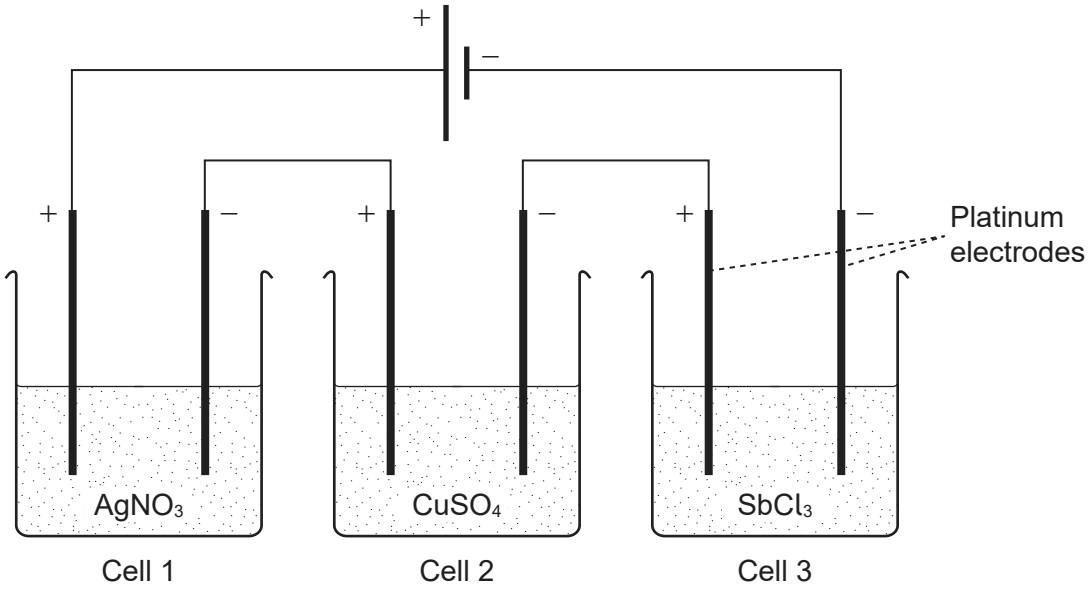
B. 1.34

C. 2.62

D. 3.54

31. What is the order of **increasing** mass deposited by this electrolytic cell?

A_r Ag = 108, Cu = 64, Sb = 122



A. Ag < Cu < Sb

B. Sb < Ag < Cu

C. Cu < Ag < Sb

D. Cu < Sb < Ag

32. Which sequence of reagents converts propene to propanone?

	First reagent added	**2nd reagent added to product**	**3rd reagent added to product of 2nd reaction**
A.	HCl	NaOH	$KMnO_4$
B.	HCl	$KMnO_4$	NaOH
C.	$KMnO_4$	HCl	NaOH
D.	$KMnO_4$	NaOH	HCl

33. How many dichlorinated butane isomers can be formed by the halogenation of $CH_3CH_2CH_2CH_3$ with excess Cl_2 in the presence of UV light?

A. 4

B. 6

C. 8

D. 10

34. Which is a homologous series?

A. C_2H_4, C_3H_5, C_4H_6

B. C_2H_2, C_3H_4, C_4H_6

C. C_2H_2, C_2H_4, C_2H_6

D. C_2H_2, C_4H_4, C_6H_6

35. Which reaction involves homolytic fission?

A. $CH_4 + Cl_2$

B. $CH_3Br + NaOH$

C. $(CH_3)_3CBr + NaOH$

D. $C_6H_6 + HNO_3 + H_2SO_4$

36. Which structure represents a repeating unit of a polymer formed from propene?

A. $–CH_2–CH(CH_3)–$

B. $–CH_2–CH_2–CH_2–$

C. $–CH(CH_3)–CH(CH_3)–$

D. $–CH_2–CH_2–$

37. What is the product of the reaction of propanal with lithium aluminium hydride, $LiAlH_4$?

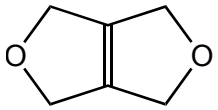
A. Propanoic acid

B. Propanone

C. Propan-1-ol

D. Propan-2-ol

38. How many signals are observed in the ^{1}H NMR spectrum of this compound?



A. 1

B. 2

C. 3

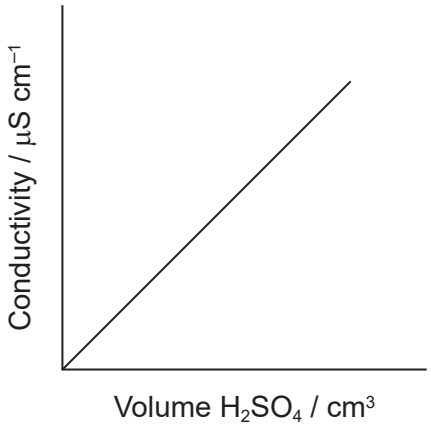
D. 4

39. 20 cm^3 of 1 mol dm^{-3} sulfuric acid was added dropwise to 20 cm^3 of 1 mol dm^{-3} barium hydroxide producing a precipitate of barium sulfate.

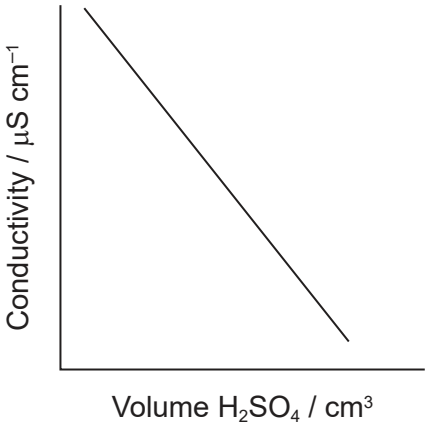
$$H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow 2H_2O(l) + BaSO_4(s)$$

Which graph represents a plot of conductivity against volume of acid added?

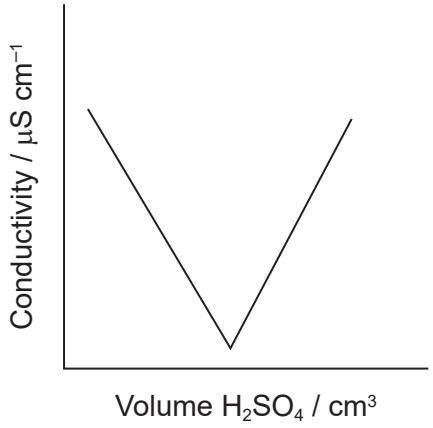
A.



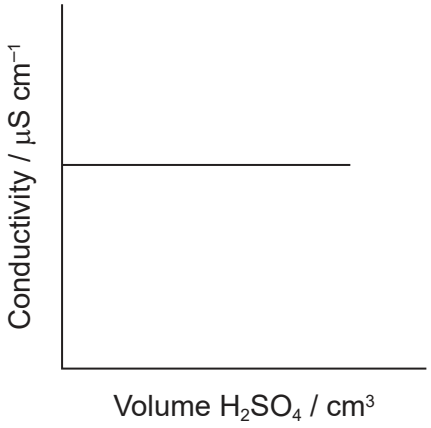
B.



C.



D.



40. Given equimolar concentrations, which substance would produce the strongest signal in a ^{1}H NMR spectrum?

A. $(CH_3)_3CH$

B. C_6H_6

C. C_8H_{18}

D. $Si(CH_3)_4$

References: