Diploma Programme
Programme du diplôme
Programa del Diploma

# Chemistry
# Higher level
# Paper 1

8 May 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]**.

2224 – 6207

17 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) |



2224–6207

**1.** Which of the following are homogeneous mixtures?

I. An aqueous solution of sodium chloride

II. A mixture of pentane and hexane

III. A mixture of ethanol and water

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**2.** Which compound has the highest percentage of carbon by mass?

A. $CH_4$

B. $C_2H_6$

C. CO

D. $CO_2$

**3.** 6.00 mol of copper, Cu, are mixed with 12.00 mol of dilute nitric acid, $HNO_3(aq)$. The equation for the reaction that occurs is shown below.

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

What is the amount, in mol, of nitrogen(II) oxide, NO, produced assuming that the reaction goes to completion?

A. 3.00

B. 4.00

C. 8.00

D. 18.00

**4.** What is the maximum number of electrons that can occupy the fourth shell in the atom ($n = 4$)?

A. 8

B. 18

C. 32

D. 36

**5.** How are the lines in the emission spectrum of hydrogen produced?

A. Electrons move to higher energy levels absorbing photons.

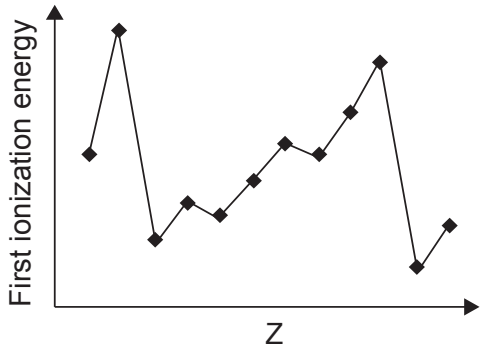
B. Electrons move to lower energy levels releasing photons.

C. Electrons move to higher energy levels releasing photons.

D. Electrons move to lower energy levels absorbing photons.

**6.** Which graph shows the correct trend in the first ionization energies of the first twelve elements in the periodic table?

A.

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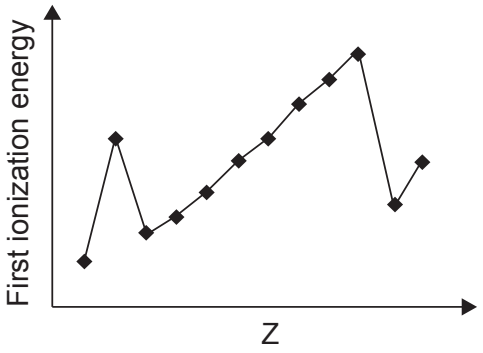


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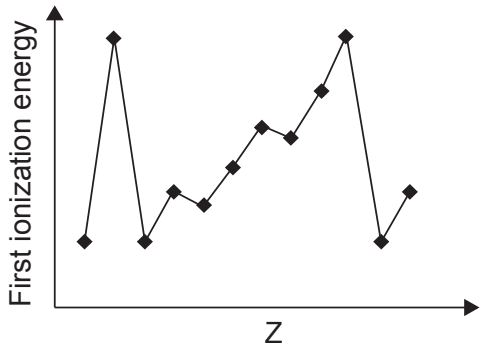
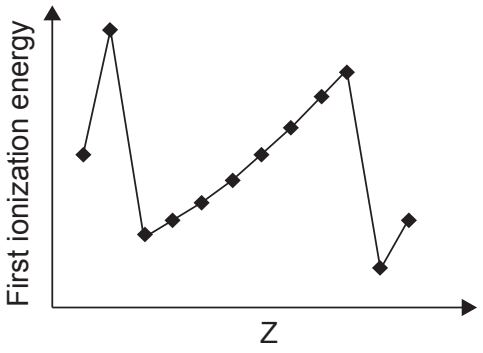



D.




**7.** Which set of ions shows **increasing** ionic radii?

A. $P^{3-} < Cl^{-} < K^{+} < Ca^{2+}$

B. $Cl^{-} < P^{3-} < Ca^{2+} < K^{+}$

C. $K^{+} < Ca^{2+} < P^{3-} < Cl^{-}$

D. $Ca^{2+} < K^{+} < Cl^{-} < P^{3-}$

**8.** When the same amount of each oxide is added to an equal volume of water, which oxide produces the solution with the highest pH?

A. $MgO$

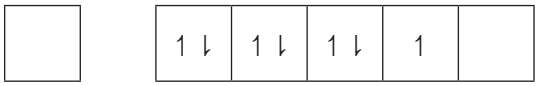
B. $Al_2O_3$

C. $SiO_2$

D. $SO_2$

**9.** In which diagram are the 4s and 3d orbitals of the $Co^{2+}$ ion correctly filled with electrons?

A.

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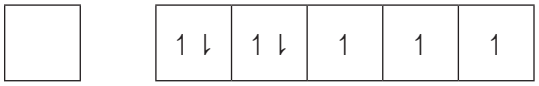
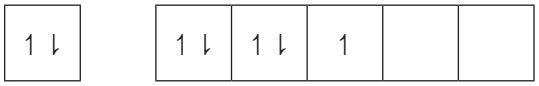



C.


D.




**10.** In which species is the oxidation state of chromium different?

A. $[Cr(H_2O)_4Cl_2]^+$

B. $[Cr(H_2O)_3(OH)_3]$

C. $[Cr(NH_3)_6]^{3+}$

D. $CrO_3$

**11.** What is the geometry around a carbon atom in graphene?

A. Hexagonal

B. Pyramidal

C. Tetrahedral

D. Trigonal planar

**12.** What is the correct number of bonding pairs of electrons in ethanedioic acid, $(COOH)_2$?

A. 7

B. 8

C. 9

D. 18

**13.** Which best explains the malleability of metals?

A. Delocalized electrons can move throughout the anion lattice.

B. Layers of anions are held together by delocalized electrons.

C. Non-directional bonds allow layers of cations to slide over each other.

D. The attraction between the cations and the delocalized electrons is strong.

**14.** What are the numbers of sigma and pi bonds in propanenitrile, $CH_3CH_2CN$?

| | Sigma | Pi |
|---|---|---|
| A. | 6 | 2 |
| B. | 7 | 3 |
| C. | 8 | 2 |
| D. | 9 | 1 |

**15.** Which molecule is non-polar?

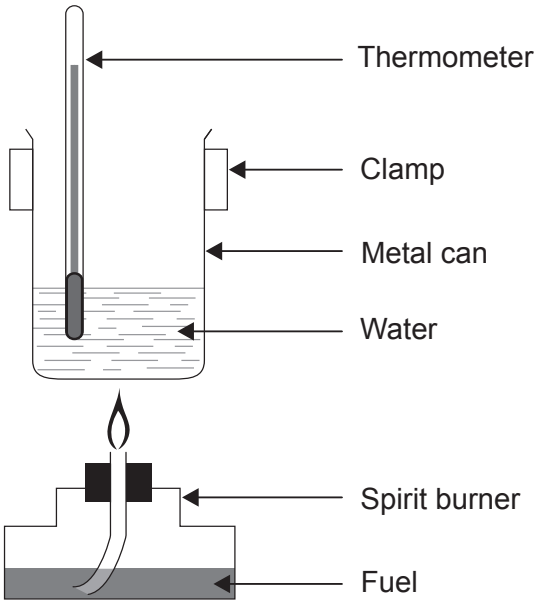
A. $XeF_2$

B. $IF_5$

C. $SF_2$

D. $PF_3$

**16.** A student determined the enthalpy change of combustion of a fuel by burning it in a spirit burner placed under a metal can containing 100 $cm^3$ of water.




Which modification can improve the accuracy of the experiment?

A. Placing a lid on the metal can containing water

B. Covering the spirit burner with aluminium foil

C. Increasing the distance between the metal can and the spirit burner

D. Using warm water instead of water at room temperature in the metal can

**17.** Standard enthalpy changes of reaction are provided for the following reactions.

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\ominus} = -394\,kJ$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -286\,kJ$$

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H^{\ominus} = -1367\,kJ$$

What is the standard enthalpy change, in kJ, of the following reaction?

$$2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$$

A. $(-394 \times 2) - (286 \times 3) - 1367$

B. $(394 \times 2) + (286 \times 3) + 1367$

C. $(394 \times 2) + (286 \times 3) - 1367$

D. $(-394 \times 2) - (286 \times 3) + 1367$

**18.** Which compound has the smallest lattice enthalpy?

A. RbBr

B. SrO

C. $MgBr_2$

D. $Na_2O$

**19.** Which equation represents the enthalpy of hydration of bromide ions?

A. $Br_2(g) \rightarrow 2Br^-(aq)$

B. $Br_2(l) \rightarrow 2Br^-(aq)$

C. $Br^-(g) \rightarrow Br^-(aq)$

D. $Br^-(s) \rightarrow Br^-(aq)$

**20.** Which best explains the low rate of a reaction between two gases occurring at high temperature and high pressure?

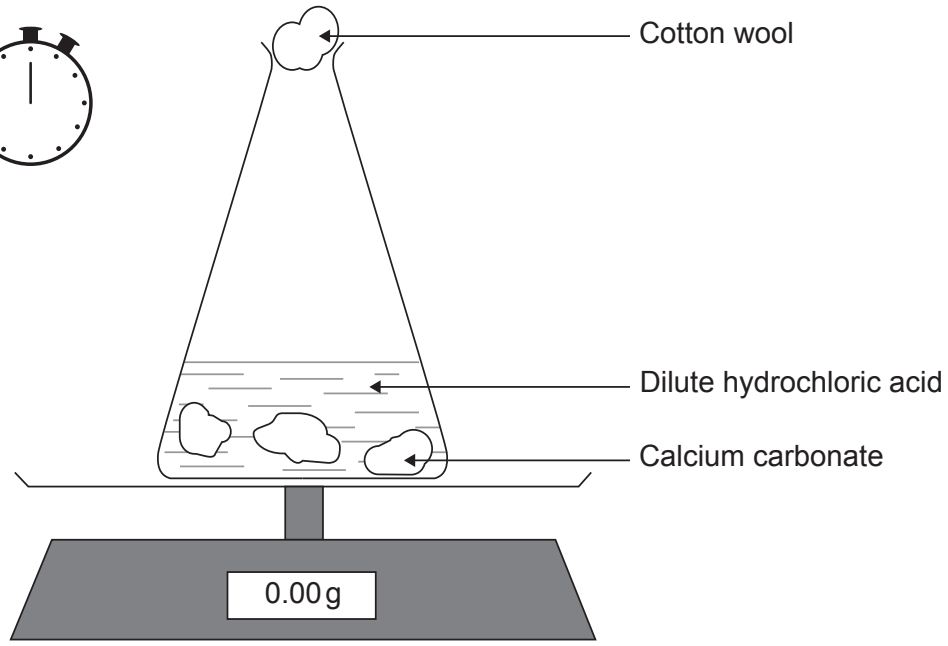
A. The frequency of collisions is low.

B. The bonds in the reactants are strong.

C. A high fraction of reactant molecules collides with the correct orientation.

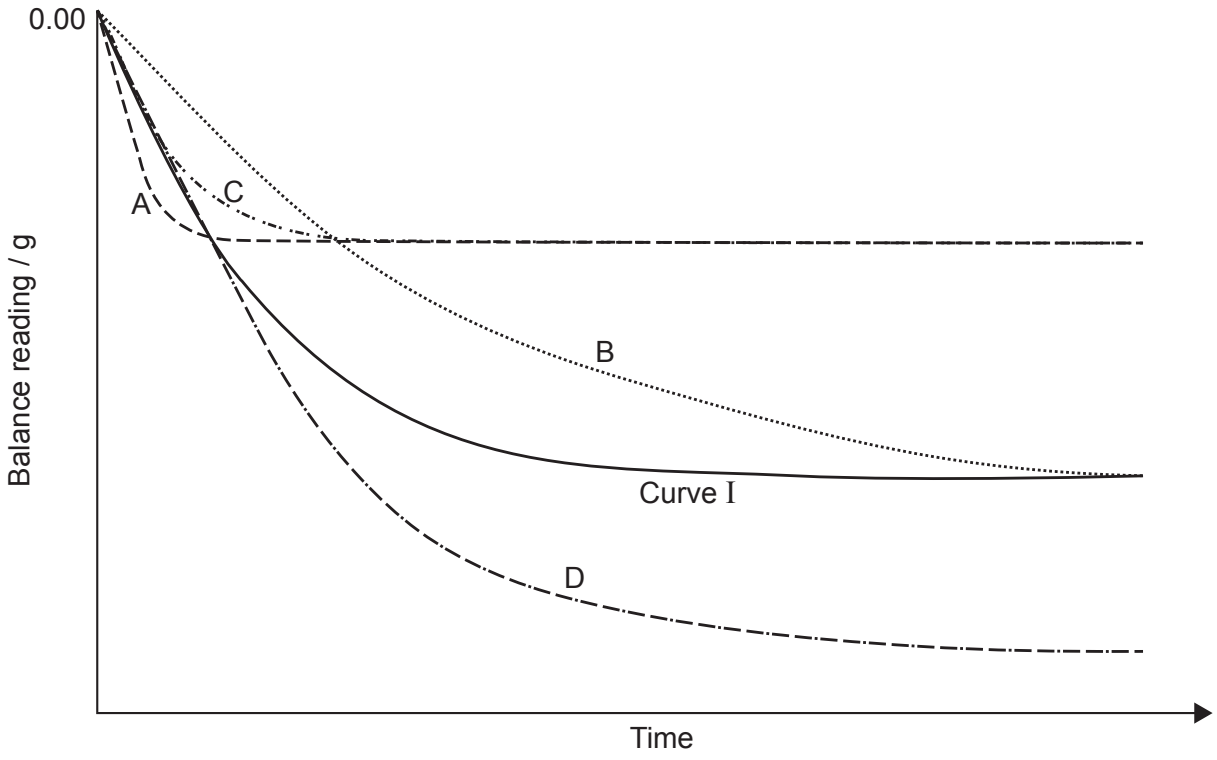
D. The activation energy of the reaction is low.

**21.** The mass of a flask containing excess calcium carbonate, $CaCO_3(s)$, reacting with 100 $cm^3$ of 0.50 mol $dm^{-3}$ hydrochloric acid, HCl (aq), was monitored with time at 25 °C.

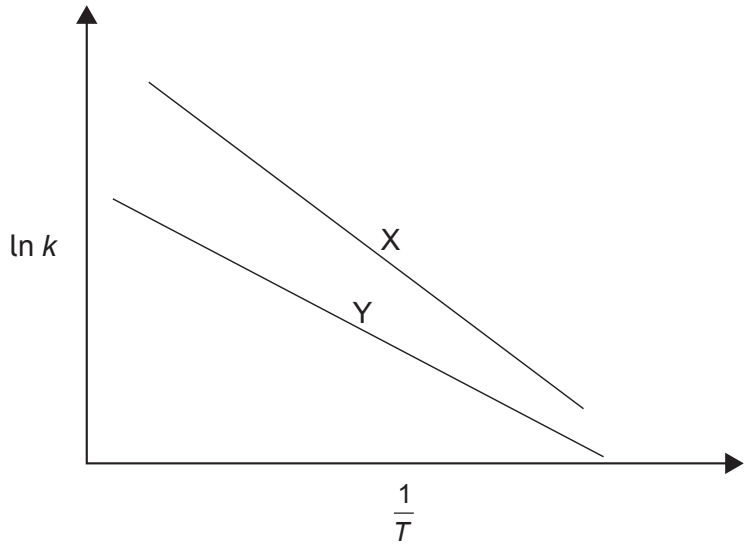



Curve I was obtained under these conditions.

Which curve corresponds to the experiment when it was repeated at the same temperature using the same mass of same sized pieces of calcium carbonate and 50 $cm^3$ of 0.50 mol $dm^{-3}$ hydrochloric acid?



**22.** The graphs below show a plot of ln $k$ against $\frac{1}{T}$ for reactions X and Y.




Considering the Arrhenius equation

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

which combination is correct for reactions X and Y?

| | Value of $E_a$ | Value of $A$ |
|---|---|---|
| A. | X > Y | X > Y |
| B. | X > Y | Y > X |
| C. | Y > X | X > Y |
| D. | Y > X | Y > X |

**23.** A reaction proceeds by the following mechanism.

Step 1: $N + P \rightarrow Q$ slow
Step 2: $Q + P \rightarrow R + N$ fast

Which statement is correct about the reaction?

A. The overall equation for the reaction is $2P \rightarrow R + Q$.

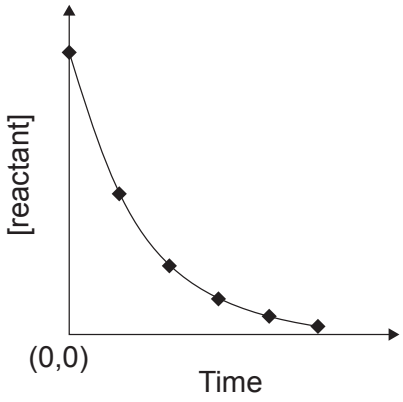
B. Q is an intermediate.

C. The overall order of the reaction is three.

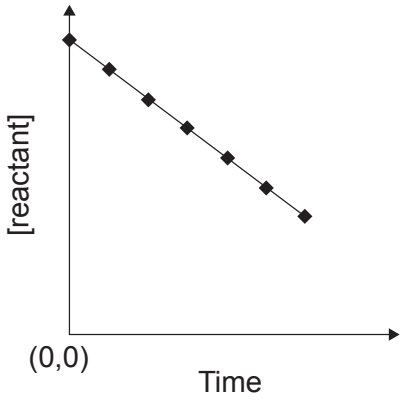
D. The rate constant has the units $s^{-1}$.

**24.** Which graph is correct for a first order reaction?

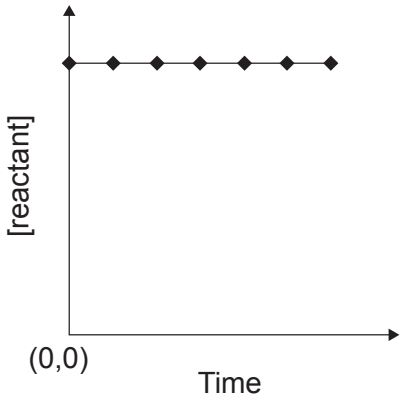
A.



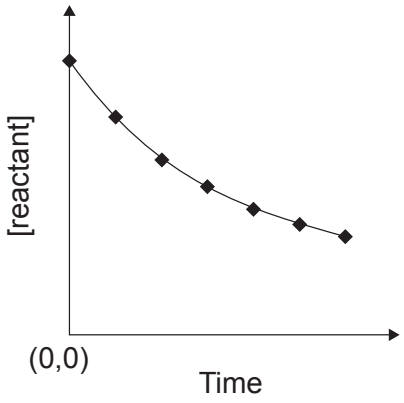

B.




C.




D.




**25.** Which pair of changes will both shift the position of equilibrium to the left?

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -92\,kJ$$

| | Temperature | Pressure |
|---|---|---|
| A. | increase | increase |
| B. | decrease | decrease |
| C. | increase | decrease |
| D. | decrease | increase |

**26.** 1.2 mol of X are mixed with 0.6 mol of Y and allowed to reach equilibrium in a 1.0 $dm^3$ container at a certain temperature.

$$2X\,(g) + Y\,(g) \rightleftharpoons 2Z\,(g)$$

There was 1.0 mol of Z present in the container at equilibrium.

What is the value of $K_c$ at this temperature?

A. 0.004

B. 0.02

C. 50

D. 250

**27.** What is the ratio of $[H^+]$ in ethanoic acid with a pH = 3 to $[H^+]$ in water at 298 K?

A. 3:7

B. 7:3

C. $1:10^4$

D. $10^4:1$

**28.** What is the conjugate base of $OH^-$?

A. $O^{2-}$

B. $H_2O$

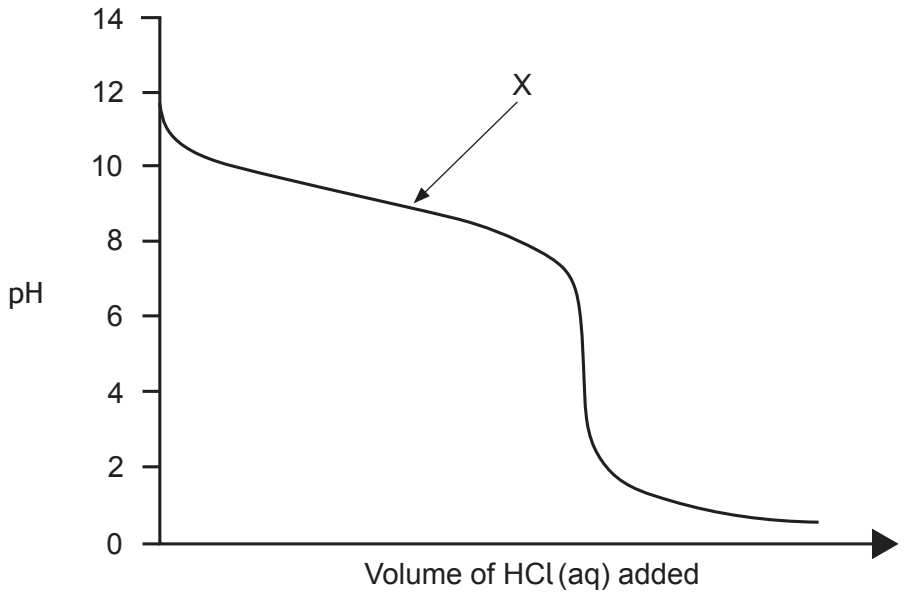
C. $H_3O^+$

D. $H^-$

**29.** Which combination is correct for a very weak acid and its conjugate base?

| | **p$K_a$ of acid** | **$K_b$ of conjugate base** |
|---|---|---|
| A. | low | low |
| B. | low | high |
| C. | high | low |
| D. | high | high |

**30.** The pH curve below is produced when aqueous ammonia is titrated with hydrochloric acid.




Besides water, which species are the major components of the reaction mixture at point X of the pH curve?

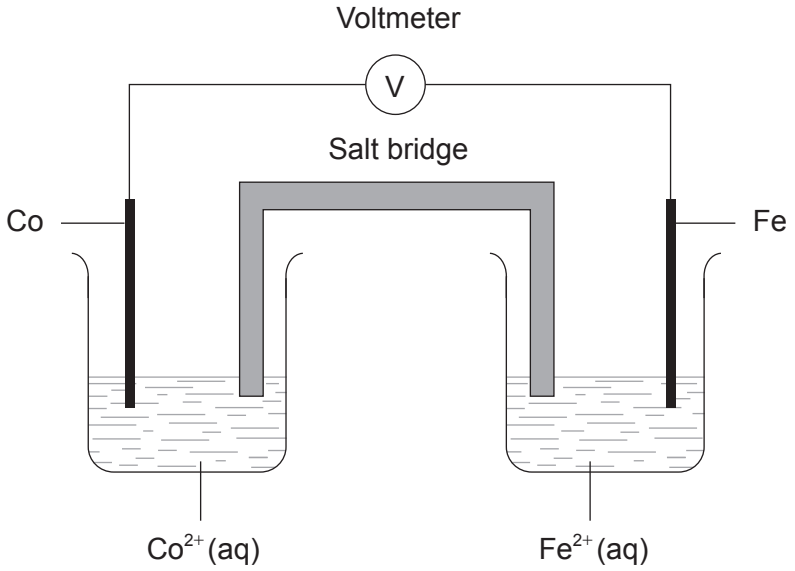
A. $NH_3$ only

B. $H^+$ only

C. $NH_3$ and $NH_4^+$

D. $H^+$ and $NH_4^+$

**31.** Iron is a more reactive metal than cobalt. Which statement is correct about the voltaic cell below?




A. Electrons flow from cobalt to iron in the wire.

B. Negative ions flow through the salt bridge to the iron half-cell.

C. The mass of the cobalt electrode decreases.

D. Reduction occurs at the iron electrode.

**32.** Which of the following occurs during the Winkler test used to determine the concentration of dissolved oxygen in water?

Step I: $2Mn^{2+}(ag) + O_2(g) + 4OH^-(aq) \rightarrow 2MnO_2(s) + 2H_2O(l)$

Step II: $MnO_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$

Step III: $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

A. Manganese(II) species is oxidized.

B. Iodine is reduced by oxygen to iodide ions.

C. Oxygen is oxidized.

D. Thiosulfate ions are reduced.

**33.** The same current flows for the same length of time through two different electrolytic cells, one containing molten sodium chloride and the other molten magnesium chloride. Which statement is correct?

A. The masses of sodium and magnesium metals produced are equal.

B. The amounts, in mol, of sodium and magnesium metals produced are equal.

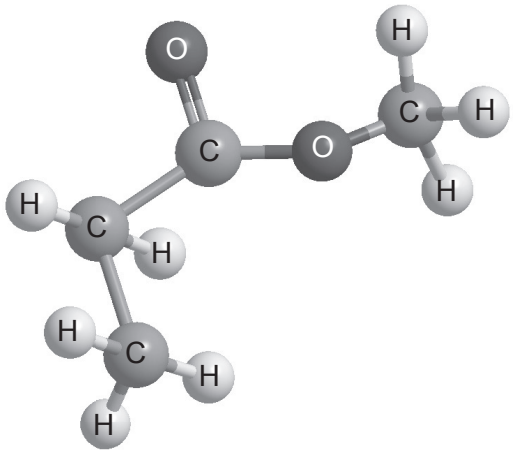
C. The mass of sodium produced is larger than the mass of magnesium produced.

D. The amount, in mol, of magnesium produced is larger than the amount of sodium produced.

**34.** Which combination is correct for a spontaneous reaction?

| | $E^{\ominus}$ | $\Delta G^{\ominus}$ |
|---|---|---|
| A. | positive | positive |
| B. | positive | negative |
| C. | negative | positive |
| D. | negative | negative |

**35.** What is the IUPAC name of this compound?




A. Methyl ethanoate

B. Ethyl methanoate

C. Methyl propanoate

D. Propyl methanoate

**36.** What is the major product formed when $Cl_2$ is added to propene?

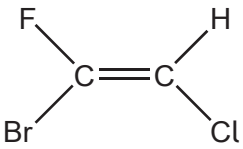
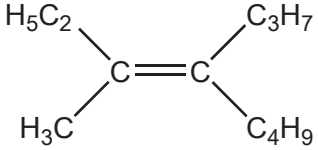
A. 2,2-dichloropropane

B. 1,2-dichloropropane

C. 1-chloroprop-2-ene

D. 2-chloropropane

**37.** Which combination labels the isomers correctly?

| |  |  |
|---|---|---|
| A. | *Z* | *Z* |
| B. | *Z* | *E* |
| C. | *E* | *E* |
| D. | *E* | *Z* |

**38.** Benzene, $C_6H_6$, can be converted to phenylamine, $C_6H_5NH_2$, in a three-stage process. The organic compounds involved in each stage are shown below.

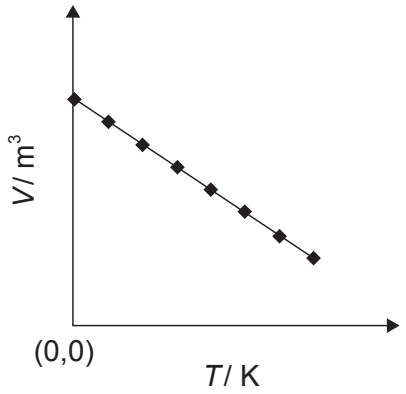
Stage I: $C_6H_6 \rightarrow C_6H_5NO_2$
Stage II: $C_6H_5NO_2 \rightarrow C_6H_5NH_3^+$
Stage III: $C_6H_5NH_3^+ \rightarrow C_6H_5NH_2$

What are the correct reagents for stages I–III?

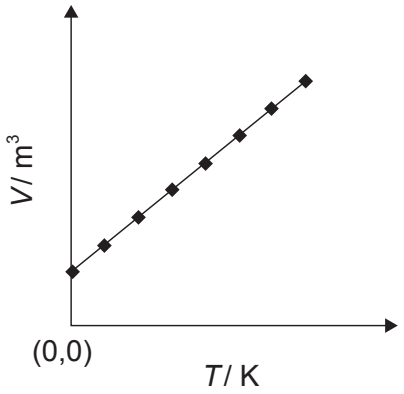
| | **Stage I** | **Stage II** | **Stage III** |
|---|---|---|---|
| A. | $H_2SO_4$ and $HNO_3$ | HCl and Sn | NaOH |
| B. | $H_2SO_4$ and $HNO_3$ | $NH_3$ | NaOH |
| C. | $HNO_2$ | HCl and Sn | NaOH |
| D. | $HNO_2$ | $NH_3$ | HCl |

**39.** Which graph shows the correct relationship between the volume and temperature of an ideal gas at constant pressure?

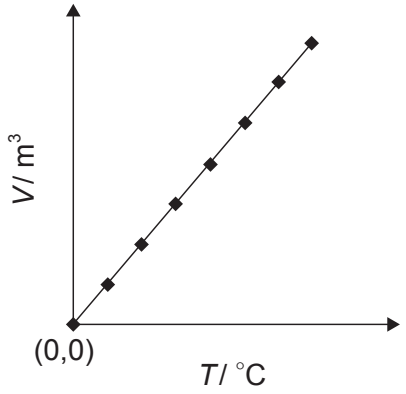
A.



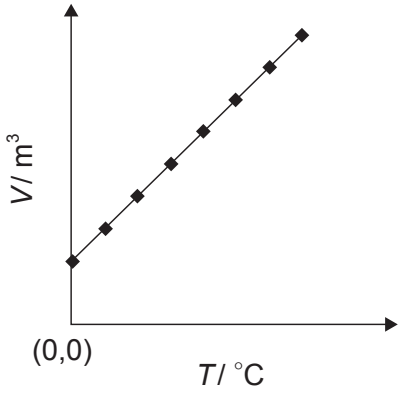

B.




C.




D.




**40.** What are the number of signals and the splitting of these signals in the $^{1}H$ NMR spectrum of propanone?

| | Number of signals | Splitting of signals |
|---|---|---|
| A. | 1 | singlet |
| B. | 1 | quartet |
| C. | 2 | triplet |
| D. | 2 | quartet |