Chemistry
Higher level
Paper 1

IB Chemistry HL prediction paper 1

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 (not provided).
- The periodic table is provided for reference on page 2 of this examination paper.
- This product is an unofficial resource and is not affiliated with, endorsed by, or produced by the International Baccalaureate Organization (IBO).
- The maximum mark for this examination paper is **[40 marks]**.

24 pages

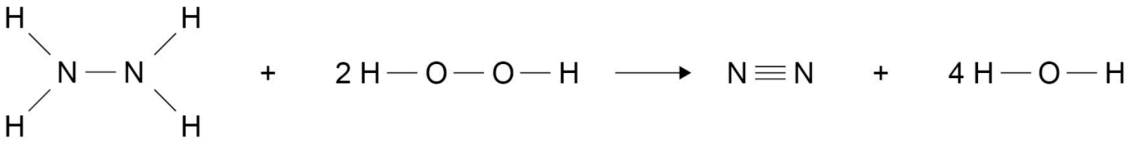
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01						Atomic number **Element** Relative atomic mass											2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											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** 207.20	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 **Uuq** (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 fuel releases the greatest energy per mole of CO_2 produced on complete combustion?

	Fuel	ΔHc / kJ mol^{-1}	CO_2 per mol fuel
A.	Methane, CH_4	–890	1
B.	Ethanol, C_2H_5OH	–1370	2
C.	Propane, C_3H_8	–2220	3
D.	Octane, C_8H_{18}	–5470	8

2. The equation below represents the combustion-type oxidation of hydrazine by hydrogen peroxide in the gas phase.



The enthalpy change for this reaction, ΔH = –789 kJ mol^{-1}

For the complete conversion of hydrazine, what is the enthalpy change, in kJ, for producing **3.00 mol** of $N_2(g)$?

A. -2.63×10^2 kJ.

B. -7.89×10^2 kJ.

C. -1.58×10^3 kJ.

D. -2.37×10^3 kJ.

3. Which species acts as a Lewis base and a bidentate ligand in transition-metal complexes?

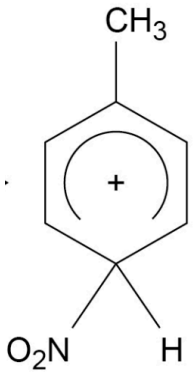
A. CN^-.

B. NH_3.

C. $C_2O_4^{2-}$.

D. H_2O.

4. The diagram shows the σ-complex (arenium ion) formed in the first step of the nitration of methylbenzene.



At which relative position to the CH_3 group has the NO_2^+ electrophile attacked?

A. Ortho.

B. Meta.

C. Para.

D. Benzylic side-chain.

5. What is the correct formula for the ionic compound formed between barium ions and phosphate ions?

A. $BaPO_4$.

B. $Ba_3(PO_4)_2$.

C. Ba_2PO_3.

D. $Ba(PO_4)_2$.

6. Lithium fluoride, LiF, has a much higher melting point than caesium iodide, CsI. Which statement best explains this difference?

A. Li^+ and F^- have smaller ionic radii than Cs^+ and I^-, so electrostatic attraction in LiF is stronger.

B. LiF has greater covalent character because the large Cs^+ polarises I^- less effectively.

C. CsI has a higher lattice energy because its ions carry larger charges.

D. CsI forms hydrogen bonds that lower its melting point.

7. Which property of metals is most directly explained by the “sea of delocalised electrons”?

A. High density.

B. Electrical conductivity in the solid state.

C. Formation of basic oxides.

D. Low first-ionisation energies.

8. The electrical conductivity of magnesium decreases with temperature, whereas that of silicon increases. Which statement best accounts for this contrast using band theory?

A. In magnesium the conduction band is empty at low temperature but becomes populated when heated, increasing scattering.

B. Thermal vibrations in magnesium scatter delocalised electrons, lowering their mobility, while in silicon thermal energy promotes electrons across a small band gap creating extra charge carriers.

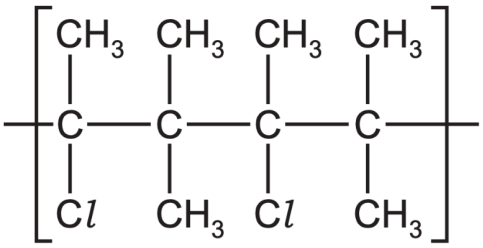
C. Magnesium has a filled valence band that widens with temperature; silicon's valence band narrows allowing easier electron flow.

D. Heating closes the band gap of both solids, but magnesium oxidises so its conductivity falls.

9. Which row correctly compares the electrical conductivity and hardness of graphite and diamond at room temperature?

	Electrical conductivity	**Hardness**
A.	Graphite: good Diamond: poor	Graphite: soft Diamond: very hard
B.	Graphite: good Diamond: good	Graphite: very hard Diamond: soft
C.	Graphite: poor Diamond: good	Graphite: soft Diamond: very hard
D.	Graphite: poor Diamond: poor	Graphite: very hard Diamond: hard

10. A section containing two repeat units of an addition polymer is shown.



What is the empirical formula of **one** repeat unit of the polymer?

A. $C_5H_{10}Cl$.

B. C_5H_9Cl.

C. C_4H_8Cl.

D. $C_5H_9Cl_2$.

11. For the reaction $2A(g) \rightarrow B(g)$ the enthalpy change $\Delta H = +40\ kJ\ mol^{-1}$ and the entropy change $\Delta S = +120\ J\ mol^{-1}\ K^{-1}$. At which temperature (T) will the reaction become spontaneous under standard conditions?

A. 250 K.

B. 300 K.

C. 330 K.

D. 600 K.

12. For the cell reaction:
$2Fe^{3+} + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+}$

Use the data:
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $E° = +0.77$ V
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$ $E° = +0.15$ V

Which pair gives the correct standard cell potential (E°cell) and standard Gibbs free-energy change (ΔG°) at 298 K?

A. $E° = +0.62$ V $\Delta G° = -1.20 \times 10^5$ J.

B. $E° = -0.62$ V $\Delta G° = +1.20 \times 10^5$ J.

C. $E° = +0.31$ V $\Delta G° = -6.0 \times 10^4$ J.

D. $E° = +0.62$ V $\Delta G° = -2.40 \times 10^5$ J.

13. Which process results in a decrease in the entropy of the system ($\Delta S < 0$)?

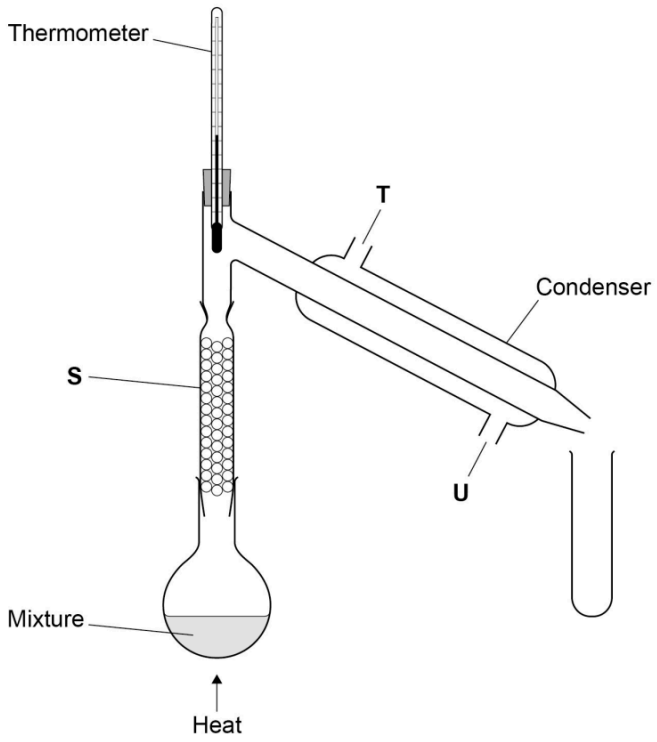
A. Sublimation of dry ice ($CO_2(s) \rightarrow CO_2(g)$).

B. Freezing of liquid water at 0 °C.

C. Vaporisation of ethanol at its boiling point.

D. Dissolution of sodium nitrate in water.

14. The apparatus below is set up for fractional distillation of a liquid mixture. The section labelled **S** contains glass beads.



What is the main purpose of the part labelled **S**?

A. To condense the vapour before it enters the condenser.

B. To provide a large surface area so vapour repeatedly condenses and revaporises, improving separation.

C. To measure the boiling point of the vapour leaving the column.

D. To prevent bumping of the boiling liquid.

15. What is the ground-state electron configuration of a sulfur atom, S?

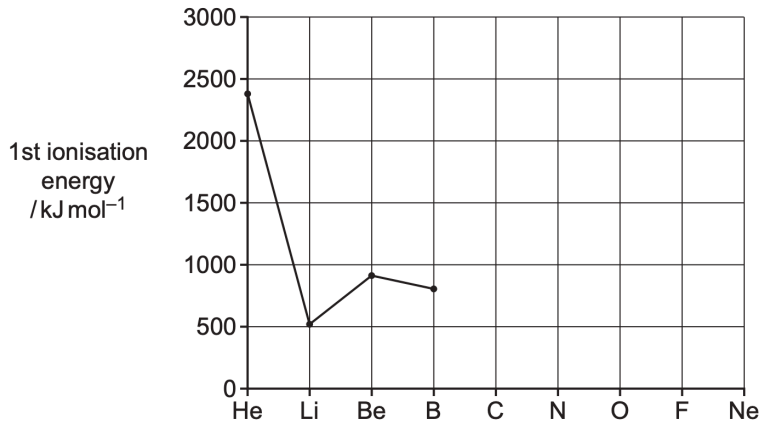
A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$.

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3\ 3d^1$.

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$.

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$.

16. The graph shows the first-ionisation energies for elements from He to B.



Which statement best accounts for the fall in first-ionisation energy from Be to B?

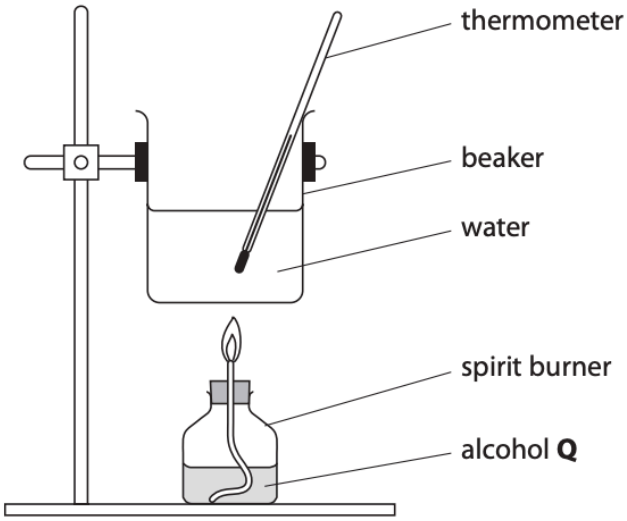
A. Nuclear charge increase is offset by repulsion between paired 2p electrons.

B. The electron removed from B occupies a 2p orbital, which is higher in energy and more shielded than the 2s orbital in Be.

C. Boron has an extra electron shell compared with Be, so its atomic radius is larger.

D. Two electrons in the same 2p orbital of B repel each other strongly.

17. The apparatus below shows a spirit-burner used to heat water in a simple calorimetry experiment.



Data

Mass of spirit burner + alcohol **Q** before combustion	= 20.24 g
Mass of spirit burner + alcohol **Q** after combustion	= 19.48 g
Mass of water in the beaker	= 500 g
Temperature of the water before the experiment	= 17.8 °C
Temperature of the water at the end of the experiment	= 28.7 °C
Specific heat capacity of water	= 4.18 $J g^{-1} °C^{-1}$

Using the data supplied, what is the experimental enthalpy change of combustion of alcohol Q per gram of fuel burned? *(Assume all heat lost to the surroundings other than the water is negligible.)*

A. 3.0×10^{1} kJ g^{-1}.

B. 3.0×10^{2} kJ g^{-1}.

C. 1.4×10^{1} kJ g^{-1}.

D. 1.4×10^{2} kJ g^{-1}.

18. Under which conditions does a real gas deviate most from ideal behaviour?

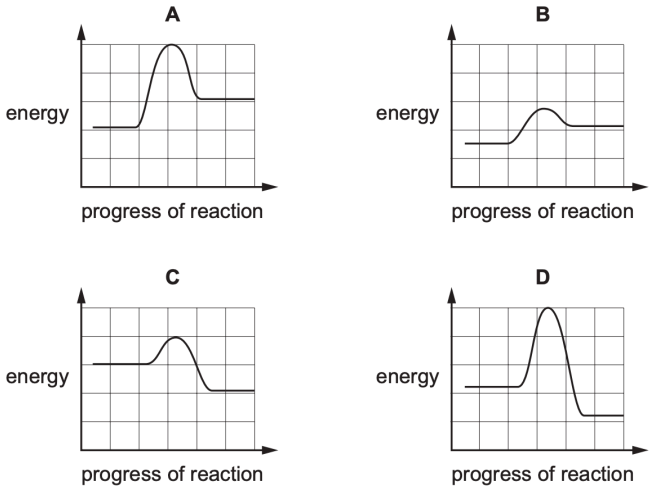
A. High T, low P.

B. High T, high P.

C. Low T, low P.

D. Low T, high P.

19. Four reaction-pathway diagrams (A–D) are shown for an endothermic reaction in which the activation energy (E_a) is numerically twice the enthalpy change (ΔH).



Which diagram correctly represents this reaction?

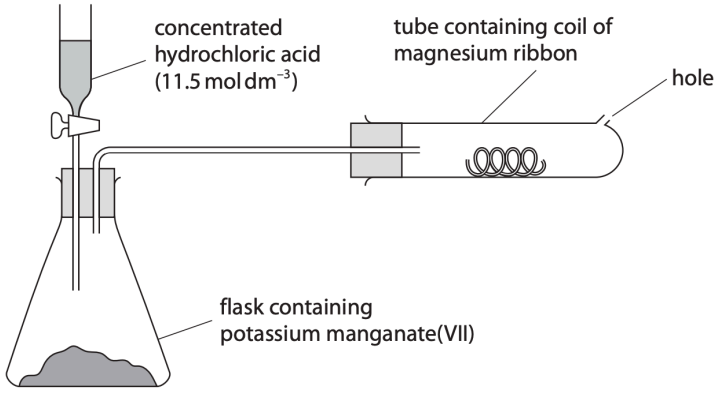
A. Diagram A.

B. Diagram B.

C. Diagram C.

D. Diagram D.

20. The apparatus below is used to react chlorine gas with a heated coil of magnesium ribbon to form magnesium chloride.



If the magnesium coil has a mass of 0.12 g and reacts completely, what mass of $MgCl_2(s)$ is produced?

A. 0.10 g.

B. 0.40 g.

C. 0.47 g.

D. 0.70 g.

21. When 2.00 g of $CaCO_3(s)$ completely decomposes at 298 K and 100 kPa, what volume of $CO_2(g)$ is produced? ($R = 8.31$ J mol^{-1} K^{-1})

A. 2.45×10^2 cm^3.

B. 4.10×10^2 cm^3.

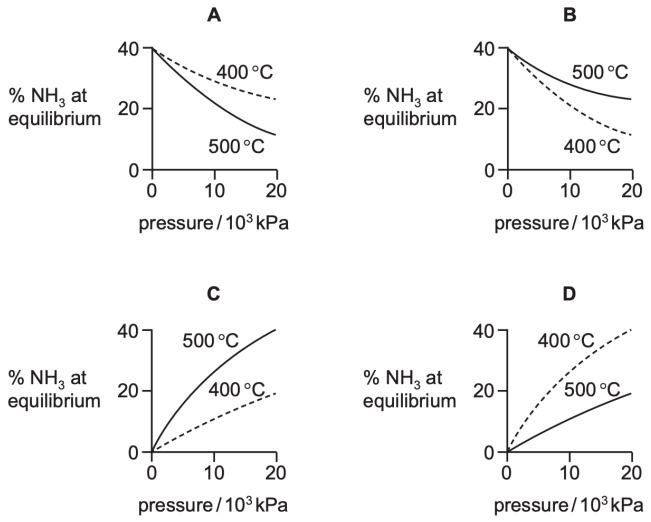
C. 4.95×10^2 cm^3.

D. 6.10×10^2 cm^3.

22. For 2 $NO_2(g) \rightleftharpoons N_2O_4(g)$ the forward reaction is exothermic. How do Kc and the equilibrium position change when the temperature is increased?

	Kc	Equilibrium position
A.	Increases	Shifts right
B.	Increases	Shifts left
C.	Decreases	Shifts right
D.	Decreases	Shifts left

23. The figure shows four possible pairs of curves (A–D) for the percentage of ammonia in equilibrium mixtures of $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$ at 400 °C and 500 °C over a range of pressures.



According to Le Châtelier's principle, which diagram correctly represents the combined effect of temperature and pressure on the equilibrium yield of ammonia?

A. Diagram A.

B. Diagram B.

C. Diagram C.

D. Diagram D.

24. For the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -58$ kJ mol^{-1}, which change increases the equilibrium concentration of N_2O_4?

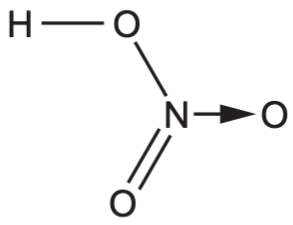
A. Raising the temperature at constant pressure.

B. Reducing the total pressure at constant temperature.

C. Increasing the pressure by decreasing the volume at constant temperature.

D. Adding argon gas at constant volume.

25. The diagram shows the skeletal formula of nitric acid with the bonding around the central nitrogen atom clearly displayed.



Nitric acid

Using VSEPR theory, what are the approximate values of the H-O-N and O-N-O bond angles in nitric acid?

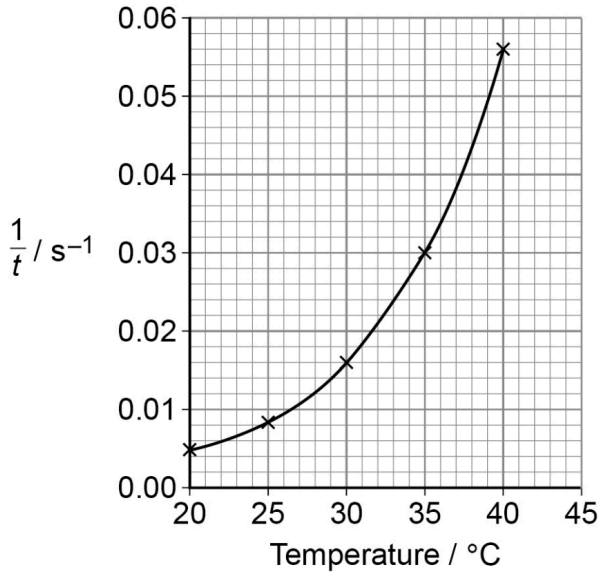
A. 104° and 120°.

B. 120° and 120°.

C. 104° and 104°.

D. 109.5° and 120°.

26. The graph displays experimental data for a reaction in the form of $1/t$ (s^{-1}) versus temperature.



Which plot of the same data would give a straight line whose gradient equals $-E_a/R$, where E_a is the activation energy?

A. ln t versus T (K).

B. ln $(1/t)$ versus $1/T$ (K^{-1}).

C. $1/t$ versus T (°C).

D. $1/t$ versus $1/T$ (K^{-1}).

27. Initial-rate data for the reaction A + B → products are:

Exp.	[A]/mol dm^{-3}	[B]/mol dm^{-3}	Rate/mol dm^{-3} s^{-1}
1	0.10	0.10	1.2×10^{-3}
2	0.10	0.20	2.4×10^{-3}
3	0.20	0.10	4.8×10^{-3}

Which proposed mechanism is consistent with these data?

A. Fast A + A ⇌ A_2 ; Slow A_2 + B → products.

B. Slow A + B → Intermediate ; Fast Intermediate + A → products.

C. Slow A + A → Intermediate ; Fast Intermediate + B → products.

D. Fast A + B ⇌ AB ; Slow AB → products.

28. What is the pH of a 1.0×10^{-3} mol dm^{-3} solution of HCl(aq) at 298 K?

A. 1.

B. 2.

C. 3.

D. 4.

29. A buffer is prepared by mixing 0.10 mol dm^{-3} ethanoic acid (pK_a = 4.76) with 0.20 mol dm^{-3} sodium ethanoate. What is the resulting pH?

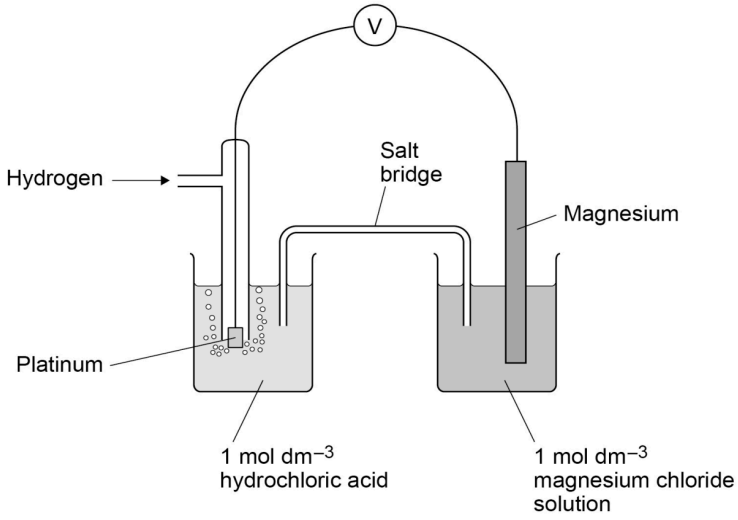
A. 4.76.

B. 5.06.

C. 5.36.

D. 5.76.

30. The diagram shows a galvanic cell used to measure the standard electrode potential of the Mg^{2+}/Mg half-cell with the standard hydrogen electrode (SHE).



Given that $E°(Mg^{2+}/Mg)$ = –2.37 V and $E°(H^+/H_2)$ = 0.00 V, what is the standard cell potential and the direction of electron flow when the circuit is completed?

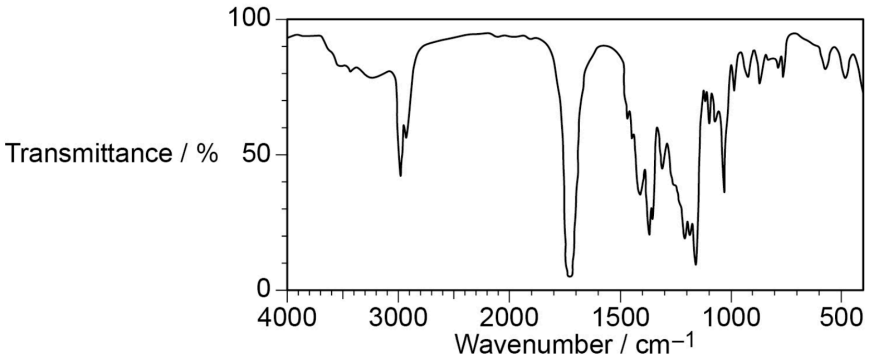
A. E°cell = –2.37 V; electrons flow from platinum to magnesium.

B. E°cell = +2.37 V; electrons flow from magnesium to platinum.

C. E°cell = +0.00 V; no net electron flow occurs.

D. E°cell = +2.37 V; electrons flow from platinum to magnesium.

31. The figure provides the infrared spectrum of an unknown organic compound Z.



Which functional group is most clearly indicated by the strong, broad absorption spanning approximately 2500 – 3300 cm^{-1} together with a sharp peak near 1700 cm^{-1}?

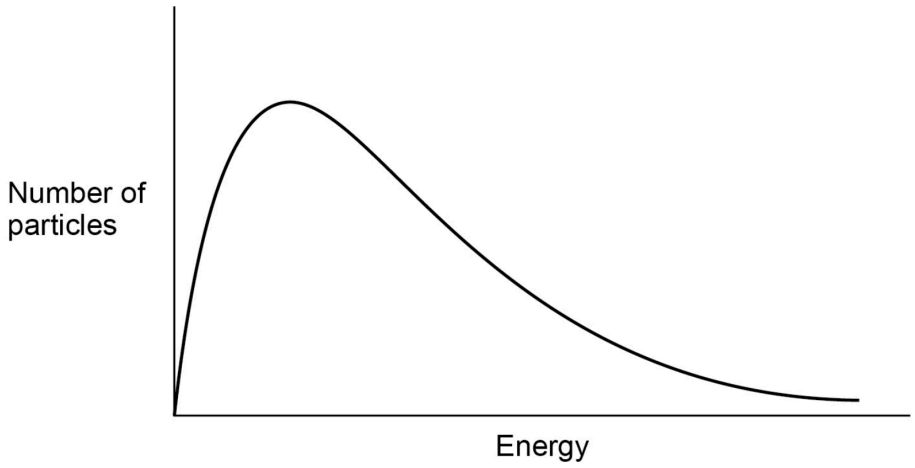
A. Alcohol (–OH).

B. Carboxylic acid (–COOH).

C. Ketone (>C=O).

D. Alkene (C=C).

32. The curve below depicts a Maxwell–Boltzmann distribution of molecular kinetic energies at temperature T.



Which change would produce a new curve whose peak is lower and shifted to higher energies while the total area under the curve remains unchanged?

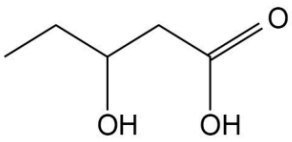
A. Decreasing the temperature of the gas.

B. Adding a solid catalyst to the gas.

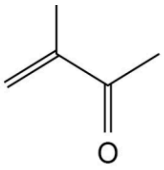
C. Increasing the temperature of the gas.

D. Doubling the pressure of the gas at constant temperature.

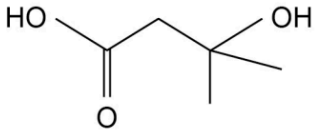
33. The figure presents four skeletal formulae for liquids J, K, L and M.



Liquid **J**



Liquid **K**



Liquid **L**

Liquid **M**

Which is the correct IUPAC name for liquid M?

A. Butanal.

B. Pentanal.

C. 1-Butanol.

D. Propanal.

34. Which functional group is present in the molecule CH_3CH_2CHO?

A. Alcohol.

B. Aldehyde.

C. Ketone.

D. Carboxylic acid.

35. Propene reacts with HBr(g) *in the absence of peroxides*. Which major product is formed?

A. 1-bromopropane.

B. 2-bromopropane.

C. 3-bromopropane.

D. Bromobenzene.

36. The hydrolysis of 2-bromo-2-methylpropane with aqueous hydroxide at 298 K follows the rate law rate = k[alkyl halide]. Which mechanism and key feature does this indicate?

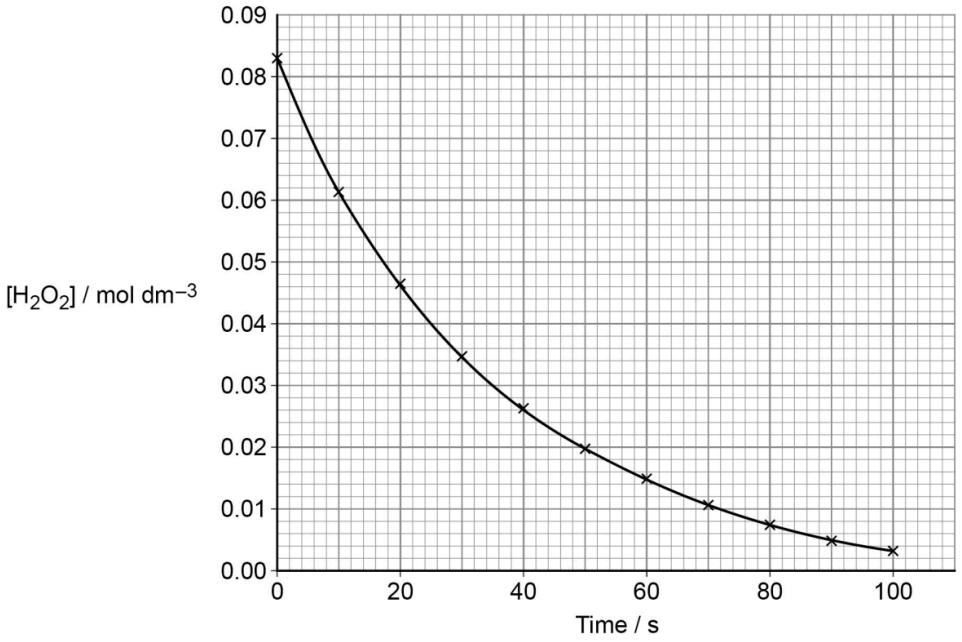
A. SN1; formation of a tertiary carbocation intermediate.

B. SN1; concerted backside attack.

C. SN2; formation of a tertiary carbocation intermediate.

D. SN2; formation of a pentacoordinate transition state involving two reactants.

37. The diagram below shows how the concentration of hydrogen peroxide varies with time during its decomposition.



Using the curve, what is the approximate initial rate of decomposition of H_2O_2 over the first 10 s?

A. 2.3×10^{-4} mol dm^{-3} s^{-1}.

B. 2.3×10^{-3} mol dm^{-3} s^{-1}.

C. 2.3×10^{-2} mol dm^{-3} s^{-1}.

D. 2.3×10^{-1} mol dm^{-3} s^{-1}.

38. Which molecule has a bond angle closest to 104.5°?

A. CH_4.

B. NH_3.

C. H_2O.

D. CO_2.

39. How many molecules are present in 0.250 mol of water, H_2O?

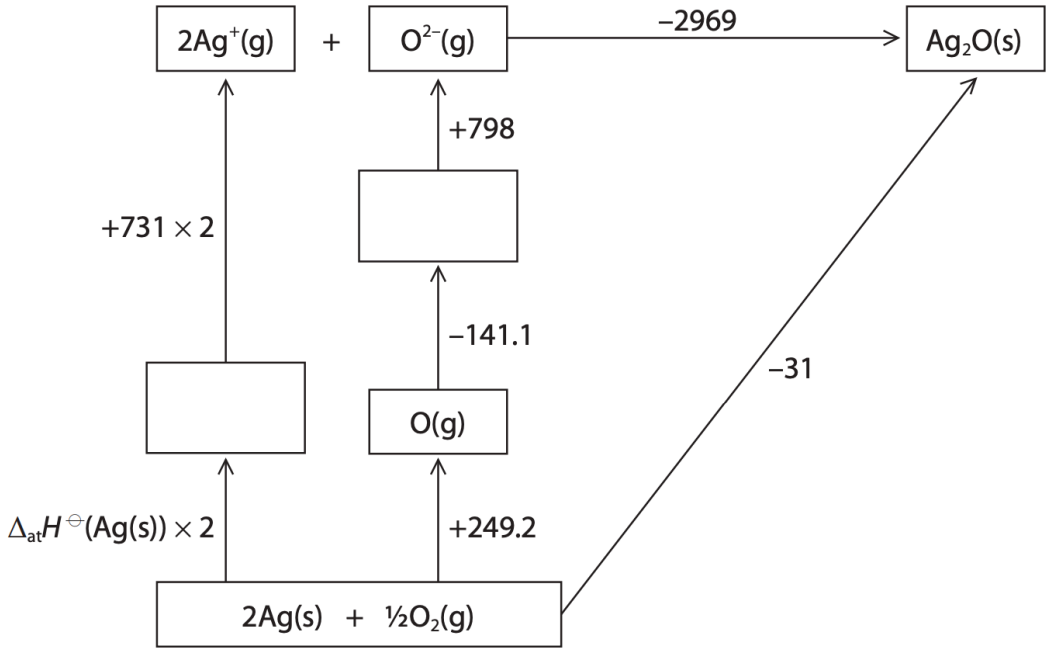
A. 6.02×10^{22}.

B. 1.51×10^{23}.

C. 3.01×10^{23}.

D. 6.02×10^{23}.

40. The Born–Haber cycle below is for the formation of silver(I) oxide, $Ag_2O(s)$. The step ($\Delta_a H^\circ$ (Ag)) is left blank.



Using the data in the diagram, what is the standard enthalpy of atomisation of silver, $\Delta_a H^\circ$ (Ag)?

A. +142 kJ mol^{-1}.

B. +250 kJ mol^{-1}.

C. +285 kJ mol^{-1}.

D. +570 kJ mol^{-1}.