Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Friday 14 May 2021 (morning)

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]**.

2221 – 6113

14 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)

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1. 0.20 mol of magnesium is mixed with 0.10 mol of hydrochloric acid.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Which is correct?

	Limiting reagent	Maximum yield of H_2 / mol
A.	HCl	0.10
B.	Mg	0.20
C.	HCl	0.05
D.	Mg	0.10

2. Which amount, in mol, of sodium chloride is needed to make 250 cm^3 of 0.10 mol dm^{-3} solution?

A. 4.0×10^{-4}

B. 0.025

C. 0.40

D. 25

3. What is the sum of the coefficients when the equation is balanced with whole numbers?

$$\_\_Sn(OH)_4(aq) + \_\_NaOH(aq) \rightarrow \_\_Na_2SnO_3(aq) + \_\_H_2O(l)$$

A. 4

B. 5

C. 6

D. 7

4. What is represented by "$^{2-}$" in ${}^{A}_{Z}X^{2-}$?

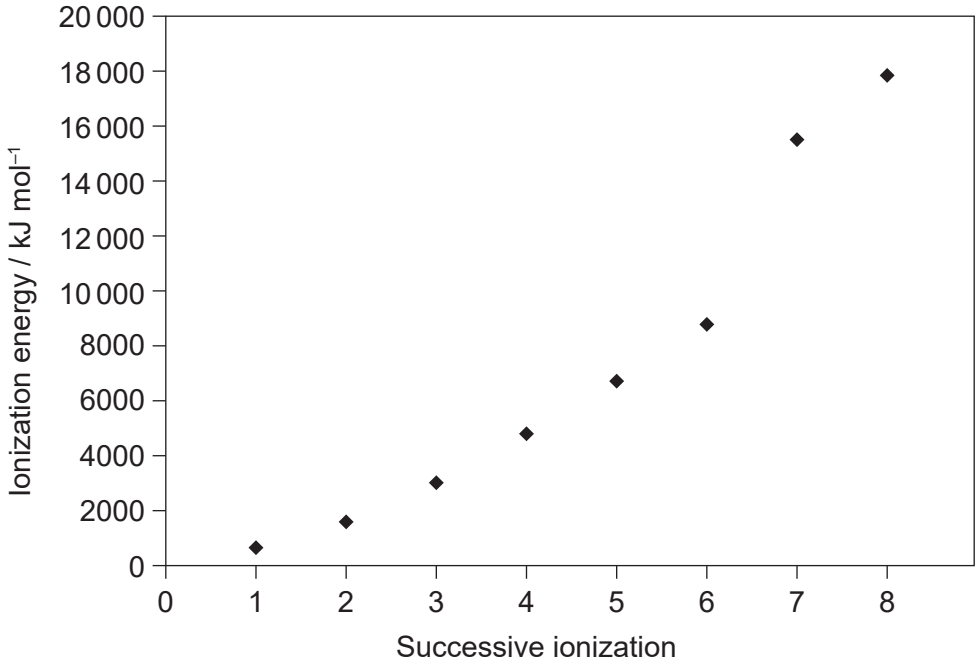
A. loss of electron

B. gain of electron

C. loss of proton

D. gain of proton

5. The first eight successive ionization energies for an element are shown. In which group is the element?



A. 6

B. 7

C. 8

D. 17

6. Which property increases down group 1?

A. atomic radius

B. electronegativity

C. first ionization energy

D. melting point

7. Which is a d-block element?

A. Ca

B. Cf

C. Cl

D. Co

8. Which factor does **not** affect the colour of a complex ion?

A. temperature of the solution

B. identity of the ligand

C. identity of the metal

D. oxidation number of the metal

9. Which compound has the greatest volatility under the same conditions?

A. SO_2

B. SiO_2

C. SnO_2

D. SrO

10. Which compound has the shortest C to N bond?

A. HCN

B. $CH_3CH_2NH_2$

C. CH_3CHNH

D. $(CH_3)_2NH$

11. Which is the correct order based on **increasing** strength?

A. covalent bonds < hydrogen bonds < dipole–dipole forces < dispersion forces

B. dipole–dipole forces < dispersion forces < hydrogen bonds < covalent bonds

C. dispersion forces < dipole–dipole forces < hydrogen bonds < covalent bonds

D. dispersion forces < dipole–dipole forces < covalent bonds < hydrogen bonds

12. Which atom has an expanded octet?

A. C in CO_2

B. S in SCl_4

C. O in H_2O_2

D. P in PCl_3

13. What is the electron domain geometry of Si in SiO_2?

A. bent

B. linear

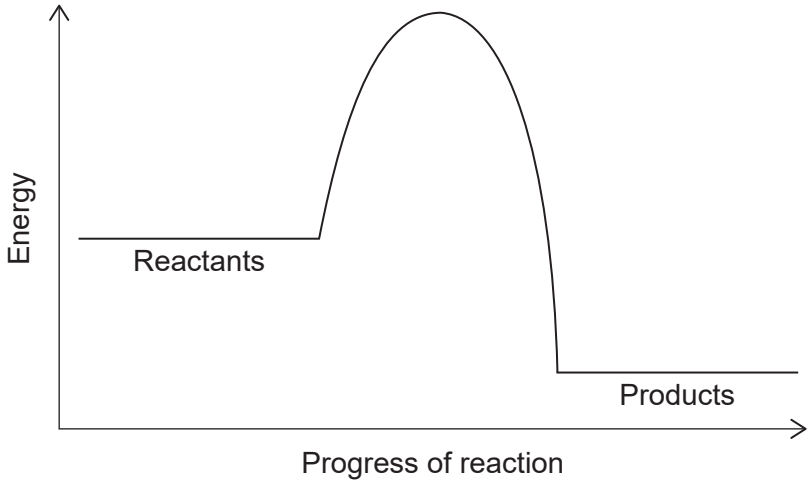
C. square planar

D. tetrahedral

14. Which describes an exothermic reaction?

	Heat transfer	Enthalpy
A.	from surroundings to system	reactants > products
B.	from surroundings to system	products > reactants
C.	from system to surroundings	products > reactants
D.	from system to surroundings	reactants > products

15. The potential energy profile of a reaction is shown.



What can be determined about stability and energy change from the potential energy profile shown?

	More stable	Reaction
A.	reactants	exothermic
B.	reactants	endothermic
C.	products	exothermic
D.	products	endothermic

16. Which represents electron affinity?

A. $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$

B. $C(g) + e^- \rightarrow C^-(g)$

C. $Cl_2(g) \rightarrow 2Cl(g)$

D. $S(s) \rightarrow S^+(g) + e^-$

17. Which change results in the largest negative value of ΔS?

A. $C_2H_5OH(l) + SOCl_2(l) \rightarrow C_2H_5Cl(l) + SO_2(g) + HCl(g)$

B. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

C. $H_2O(l) \rightarrow H_2O(s)$

D. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

18. Which change causes the greatest increase in the initial rate of reaction between nitric acid and magnesium?

$$2HNO_3(aq) + Mg(s) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

	$[HNO_3]$	**Size of metal pieces**
A.	doubled	halved
B.	doubled	doubled
C.	halved	halved
D.	halved	doubled

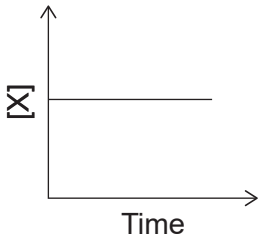
19. Which explains increasing rate of reaction with increasing temperature?

	Particles with $E > E_a$	**Frequency of collisions**
A.	same	same
B.	more	greater
C.	same	greater
D.	more	same

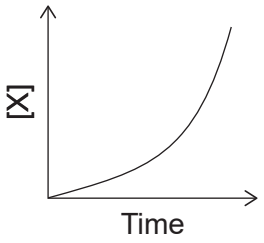
20. Which graph represents a second order reaction with respect to X?

$$X \rightarrow Y$$

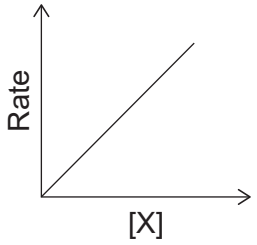
A.



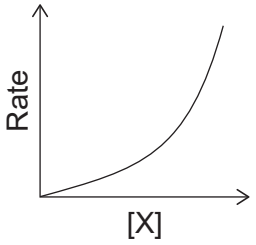
B.



C.



D.



21. Which statements are correct about the action of a catalyst in a chemical reaction?

I. It increases the energy of each collision.

II. It alters the mechanism of the reaction.

III. It remains unchanged at the end of the reaction.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

22. What effect does a catalyst have on the position of equilibrium and the value of the equilibrium constant, K_c, for an exothermic reaction?

	Position of equilibrium	**Value of equilibrium constant**
A.	moves to products	increases
B.	stays the same	increases
C.	stays the same	stays the same
D.	moves to products	stays the same

23. Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ$$

Which change increases the value of K_c?

A. increasing the temperature

B. decreasing the temperature

C. decreasing $[SO_2(g)]$

D. decreasing $[SO_3(g)]$

24. Which **cannot** act as a Brønsted–Lowry base?

A. HPO_4^{2-}

B. H_2O

C. CH_4

D. NH_3

25. Which causes acid deposition?

A. SO_2

B. SiO_2

C. SrO

D. CO_2

26. Which is correct?

A. Electrophiles are Brønsted–Lowry acids.

B. Nucleophiles are Brønsted–Lowry acids.

C. Electrophiles are Lewis acids.

D. Nucleophiles are Lewis acids.

27. Which compound is acidic in aqueous solution?

A. KBr

B. CH_3COONa

C. NH_4Cl

D. Na_2CO_3

28. What is the oxidation state of oxygen in H_2O_2?

A. –2

B. –1

C. +1

D. +2

29. What are the products of the electrolysis of molten potassium chloride, KCl (l)?

	Anode (positive electrode)	Cathode (negative electrode)
A.	K	Cl
B.	Cl_2	K
C.	Cl	K
D.	K	Cl_2

30. What would be the electrode potential, $E^{\ominus}$, of the $Mn^{2+}(aq)|Mn(s)$ half-cell if $Fe^{3+}(aq)|Fe^{2+}(aq)$ is used as the reference standard?

$$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s) \qquad E^{\ominus} = -1.18\,V$$

$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^{\ominus} = +0.77\,V$$

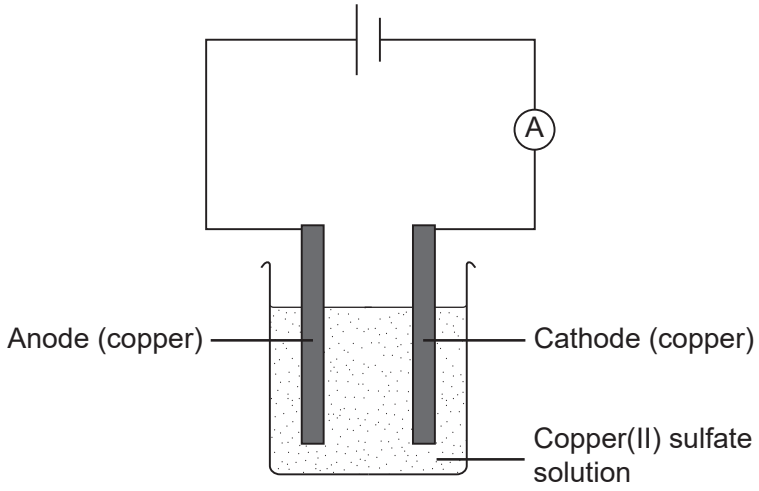
A. –1.95 V

B. –0.41 V

C. +0.41 V

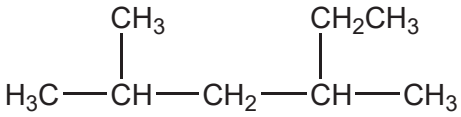
D. +1.95 V

31. What happens to the mass of each copper electrode when aqueous copper(II) sulfate solution is electrolysed?



	Anode (positive electrode)	Cathode (negative electrode)
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

32. What is the IUPAC name of the molecule shown?



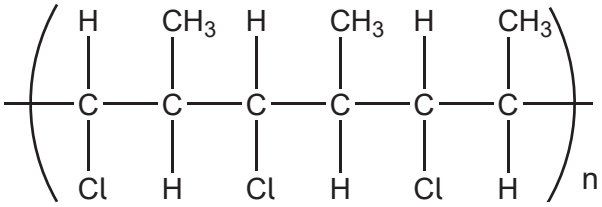
A. 2,4-dimethylhexane

B. 3,5-dimethylhexane

C. 2-methyl-4-ethylpentane

D. 2-ethyl-4-methylpentane

33. Which monomer forms the polymer shown?



A. $CH(Cl)=CH(CH_3)$

B. $CH_2=C(Cl)CH_3$

C. $(CH_3)_2CHCl$

D. $CH_2=CHCl$

34. Which is a propagation step in the free-radical substitution mechanism of ethane with chlorine?

A. $Cl_2 \rightarrow 2\ \bullet Cl$

B. $\bullet C_2H_5 + Cl_2 \rightarrow C_2H_5Cl + \bullet Cl$

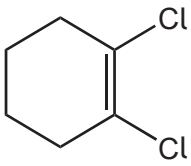
C. $\bullet C_2H_5 + \bullet Cl \rightarrow C_2H_5Cl$

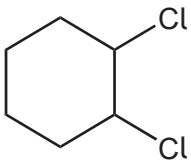
D. $C_2H_6 + \bullet Cl \rightarrow C_2H_5Cl + \bullet H$

35. Which compound shows *cis-trans* isomerism?

A. $CH_3CH=CCl_2$

B. $CCl_2=CH_2$

C. 

D. 

36. Which compound rotates the plane of plane-polarized light?

A. $CH_3C(CH_3)ClCH_3$

B. $CH_3CH_2CHClCH_3$

C. $CH_3C(Cl)_2CH_3$

D. $CH_3CClBrCH_3$

37. Which can be reduced to a secondary alcohol?

A. C_2H_5COOH

B. $CH_3CH_2OCH_3$

C. $(CH_3)_2CHCHO$

D. $CH_3COC_2H_5$

38. Which spectra would show the difference between propan-2-ol, $CH_3CH(OH)CH_3$, and propanal, CH_3CH_2CHO?

I. mass

II. infrared

III. ^1H NMR

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

39. How should the difference between 27.0 ± 0.3 and 9.0 ± 0.2 be shown?

A. 18.0 ± 0.1

B. 18.0 ± 0.3

C. 18.0 ± 0.5

D. 18.0 ± 0.6

40. What information can be deduced from the splitting pattern of ^{1}H NMR signals?

A. total number of hydrogen atoms in a compound

B. number of hydrogen atoms on adjacent atom(s)

C. functional group on which hydrogen atoms are located

D. number of hydrogen atoms in a particular chemical environment

References:

5. Copyright Prof Mark Winter.