Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Wednesday 9 November 2022 (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]**.

8822 – 6101

15 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)

1. How many oxygen atoms are present in 0.0500 mol $Ba(OH)_2 \cdot 8H_2O$?

$$N_A = 6.02 \times 10^{23}$$

A. 3.01×10^{23}

B. 6.02×10^{23}

C. 3.01×10^{24}

D. 6.02×10^{24}

2. What is the change of state for a gas to a solid?

A. Condensation

B. Deposition

C. Freezing

D. Sublimation

3. How many moles of carbon dioxide are produced by the complete combustion of 7.0 g of ethene, $C_2H_4(g)$?

$$M_r = 28$$

A. 0.25

B. 0.5

C. 0.75

D. 1.0

4. Successive ionization energies of an element, **X**, are shown.

	1st	**2nd**	**3rd**	**4th**
Ionization energy (kJ mol^{-1})	740	1450	7730	10 540

What energy, in kJ mol^{-1}, is required for element **X** to reach its most stable oxidation state in ionic compounds?

A. 740

B. 1450

C. 2190

D. 7730

5. Which quantities are different between two species represented by the notation $^{128}_{52}Te$ and $^{128}_{53}I^-$?

A. The number of protons only

B. The number of protons and electrons only

C. The number of protons and neutrons only

D. The number of protons, neutrons and electrons

6. Which best explains why complexes of d-block elements are coloured?

A. Light is absorbed when electrons are promoted between d orbitals.

B. Light is emitted when electrons are promoted between d orbitals.

C. Light is absorbed when electrons return to lower energy d orbitals.

D. Light is emitted when electrons return to lower energy d orbitals.

7. Which elements are considered to be metalloids?

I. Gallium
II. Germanium
III. Arsenic

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. Which property of elements increases down a group but decreases across a period?

A. Atomic radius

B. Electronegativity

C. Ionic radius

D. Ionization energy

9. Which molecule can be represented by resonance structures?

A. H_2S

B. HNO_3

C. H_2O_2

D. HClO

10. Which elements are capable of forming expanded octets?

I. Nitrogen
II. Phosphorus
III. Arsenic

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which molecule has a tetrahedral molecular geometry?

A. HNO_3

B. SF_4

C. XeF_4

D. XeO_4

12. Alloying a metal with a metal of smaller atomic radius can disrupt the lattice and make it more difficult for atoms to slide over each other. Which property will increase as a result?

A. Electrical conductivity

B. Ductility

C. Malleability

D. Strength

13. Chlorofluorocarbons (CFCs) contain bonds of the following lengths:

$C{-}C = 1.54 \times 10^{-10}\,m$

$C{-}F = 1.38 \times 10^{-10}\,m$

$C{-}Cl = 1.77 \times 10^{-10}\,m$

What is the order of **increasing** bond strength in the CFC molecule?

A. $C{-}C < C{-}F < C{-}Cl$

B. $C{-}C < C{-}Cl < C{-}F$

C. $C{-}Cl < C{-}C < C{-}F$

D. $C{-}F < C{-}C < C{-}Cl$

14. What is the value for enthalpy of formation of methane from the given enthalpies of combustion?

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -394\,kJ\,mol^{-1}$$

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

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -891\,kJ\,mol^{-1}$$

A. $(-394 - 286 - 891)\,kJ\,mol^{-1}$

B. $(-394 - (2 \times 286) - 891)\,kJ\,mol^{-1}$

C. $(-394 - 286 + 891)\,kJ\,mol^{-1}$

D. $(-394 - (2 \times 286) + 891)\,kJ\,mol^{-1}$

15. Which magnitudes of lattice enthalpy and hydration enthalpy of ions for an ionic substance would result in the most exothermic enthalpy of solution?

	Magnitude of lattice enthalpy	Magnitude of hydration enthalpy of ions
A.	large	large
B.	large	small
C.	small	large
D.	small	small

16. Which alkane has the lowest standard entropy, $S^{\ominus}$?

A. $CH_4(g)$

B. $C_2H_6(g)$

C. $C_3H_8(g)$

D. $C_4H_{10}(g)$

17. At which temperature could ΔH, ΔS, and ΔG all be positive?

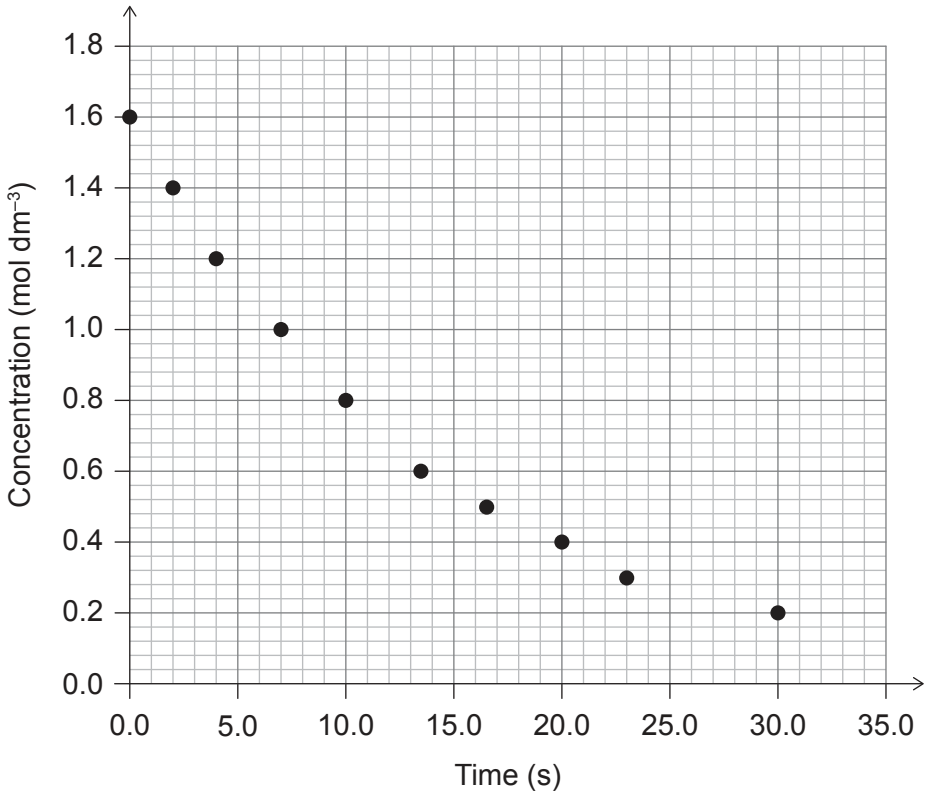
A. High temperatures

B. Low temperatures

C. Any temperature

D. No temperature

18. What initial rate of reaction can be determined from the graph?



A. 0.1 mol dm^{-3} s^{-1}

B. 0.2 mol dm^{-3} s^{-1}

C. 1.0 mol dm^{-3} s^{-1}

D. 1.6 mol dm^{-3} s^{-1}

19. Which changes would increase the rate of an exothermic reaction?

	Temperature	**Particle size**
A.	Increase	Decrease
B.	Increase	Increase
C.	Decrease	Increase
D.	Decrease	Decrease

20. Data is given for the reaction $2X_2(g) + Y_2(g) \rightarrow 2X_2Y(g)$.

$[X_2(g)]$ (mol dm^{-3})	$[Y_2(g)]$ (mol dm^{-3})	Rate (mol dm^{-3} min^{-1})
0.1	0.2	0.1
0.2	0.2	0.4
0.2	0.1	0.4

What rate equation can be inferred from the data?

A. Rate $= k\,[X_2]\,[Y_2]$

B. Rate $= k\,[X_2]^2\,[Y_2]$

C. Rate $= k\,[X_2]^2\,[Y_2]^0$

D. Rate $= k\,[X_2]^2\,[Y_2]^2$

21. The activation energy of a reaction can be obtained from the rate constant, *k*, and the absolute temperature, T. Which graph of these quantities produces a straight line?

A. *k* against T

B. *k* against $\frac{1}{T}$

C. ln *k* against T

D. ln *k* against $\frac{1}{T}$

22. For the reaction $I_2(g) + 3Cl_2(g) \rightleftharpoons 2ICl_3(g)$ at a certain temperature, the equilibrium concentrations are (in mol dm^{-3}):

$$[I_2] = 0.20,\ [Cl_2] = 0.20,\ [ICl_3] = 2.0$$

What is the value of K_c?

A. 0.25

B. 50

C. 2500

D. 5000

23. Which of these changes would shift the equilibrium to the right?

$$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(l)$$

I. Addition of 0.01 M HCl

II. Addition of concentrated HCl

III. Evaporation of water

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

24. Equal volumes of 0.10 mol dm^{-3} weak acid and strong acid are titrated with 0.10 mol dm^{-3} NaOH solution. Which of these is the same for the two acids?

A. Initial pH

B. Heat evolved in the neutralization

C. Volume of NaOH for complete neutralization

D. Initial electrical conductivity

25. Which species has the weakest conjugate base?

A. HCl

B. NH_4^+

C. HCO_3^-

D. H_2O

26. Which solutions will form a buffer when mixed?

A. 50 cm^3 of 1.0 mol dm^{-3} HCl and 50 cm^3 of 1.0 mol dm^{-3} NaOH

B. 50 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 50 cm^3 of 1.0 mol dm^{-3} NaOH

C. 50 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 100 cm^3 of 1.0 mol dm^{-3} NaOH

D. 100 cm^3 of 1.0 mol dm^{-3} CH_3COOH and 50 cm^3 of 1.0 mol dm^{-3} NaOH

27. Which species can act both as a Lewis acid and a Lewis base?

A. H_2O

B. NH_4^+

C. Cu^{2+}

D. CH_4

28. What occurs during the operation of a voltaic cell based on the given reaction?

$$2Cr(s) + 3Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Fe(s)$$

	External circuit	Ion movement in solution
A.	Electrons move from Cr to Fe	$Fe^{2+}(aq)$ move away from $Fe(s)$
B.	Electrons move from Cr to Fe	$Fe^{2+}(aq)$ move toward $Fe(s)$
C.	Electrons move from Fe to Cr	$Cr^{3+}(aq)$ move away from $Cr(s)$
D.	Electrons move from Fe to Cr	$Cr^{3+}(aq)$ move toward $Cr(s)$

29. What is the coefficient for H^+ when the equation below is balanced?

$$\_\_Pb(s) + \_\_NO_3^-(aq) + \_\_H^+(aq) \rightarrow \_\_Pb^{2+}(aq) + \_\_NO(g) + \_\_H_2O(l)$$

A. 2

B. 4

C. 6

D. 8

30. The standard electrode potentials for three half-cells involving chromium are shown.

$$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq) \qquad E^{\ominus} = -0.407\,V$$

$$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s) \qquad E^{\ominus} = -0.744\,V$$

$$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s) \qquad E^{\ominus} = -0.914\,V$$

Which statement is correct?

A. $Cr^{3+}(aq)$ can oxidize $Cr^{2+}(aq)$ but not $Cr(s)$.

B. $Cr^{3+}(aq)$ can oxidize $Cr(s)$ but not $Cr^{2+}(aq)$.

C. $Cr^{3+}(aq)$ can oxidize both $Cr^{2+}(aq)$ and $Cr(s)$.

D. $Cr^{3+}(aq)$ can oxidize $Cr(s)$ and reduce $Cr^{2+}(aq)$.

31. Which factors affect the amount, in mol, of product formed during electrolysis?

I. The charge on the ion

II. The molar mass of the ion

III. The duration of the electrolysis

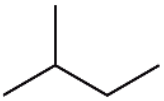
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

32. Which are isomers of C_5H_{12}?

I. 

II. 

III. 

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

33. Which compound has a chiral carbon?

A. Bromoethane

B. 2-bromopropane

C. 2-bromobutane

D. 3-bromopentane

34. Which conditions best favour oxidation of primary alcohols directly to carboxylic acids?

A. Excess acidified potassium dichromate (VI) and distillation

B. Excess acidified potassium dichromate (VI) and reflux

C. Few drops of acidified potassium dichromate (VI) and distillation

D. Few drops of acidified potassium dichromate (VI) and reflux

35. Which statement best describes retrosynthesis?

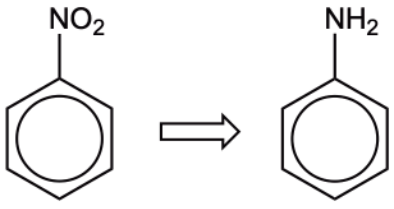
A. The reaction conditions needed to convert the product of a reaction back to the starting materials.

B. Synthesizing a target molecule by working back from the target molecule to the starting materials.

C. A synthetic scheme using traditional methods rather than modern methods and materials.

D. A synthetic pathway which favours the equilibrium towards the products.

36. What combination of reactants will convert nitrobenzene to phenylamine in two steps?



	Initial reactant(s)	Second reactant
A.	Concentrated HCl and Sn (s)	OH^- (aq)
B.	Concentrated HCl and Sn (s)	NH_4^+ (aq)
C.	Acidified potassium dichromate (VI)	OH^- (aq)
D.	Acidified potassium dichromate (VI)	NH_4^+ (aq)

37. A well tested scientific idea which has been used to make predictions cannot explain a particular event. Which statement describes the scientific approach to this dilemma?

A. Hypothesis should be discarded.

B. Hypothesis should be revised.

C. Theory should be discarded.

D. Theory should be revised.

38. What information about 2-hydroxybutanoic acid can be inferred through mass spectrometry, MS, infrared spectroscopy, IR, and proton nuclear magnetic resonance spectroscopy, ^{1}H NMR?

	MS	**IR**	**^{1}H NMR**
A.	$M = 104\,\text{g mol}^{-1}$.	Compound contains carboxyl and hydroxyl groups.	The hydroxyl group is on the 2nd, rather than 4th carbon.
B.	$M = 104\,\text{g mol}^{-1}$.	The hydroxyl group is on the 2nd, rather than 4th carbon.	Compound contains carboxyl and hydroxyl groups.
C.	Compound contains carboxyl and hydroxyl groups.	$M = 104\,\text{g mol}^{-1}$.	The hydroxyl group is on the 2nd, rather than 4th carbon.
D.	Compound contains carboxyl and hydroxyl groups.	The hydroxyl group is on the 2nd, rather than 4th carbon.	$M = 104\,\text{g mol}^{-1}$.

39. What information can be deduced about a compound through X-ray crystallography?

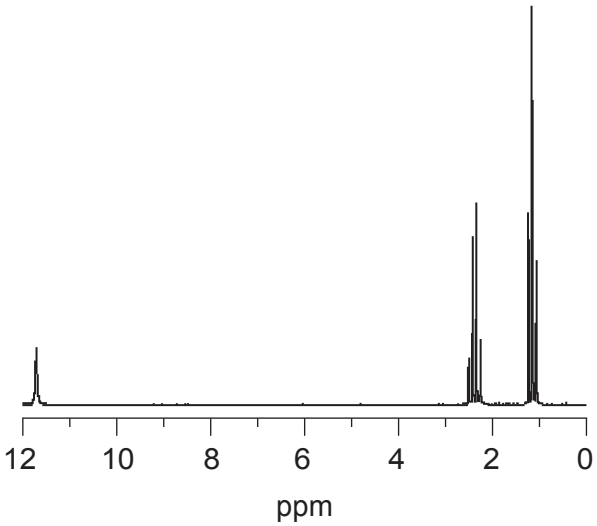
A. Boiling and melting points

B. Bond angles

C. Bonds that will break during fragmentation

D. Ionization energy

40. Which organic compound has the ^{1}H NMR shown?



A. Methanal

B. Ethanoic acid

C. Methyl ethanoate

D. Propanoic acid

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References:

40. Spectral Database for Organic Compounds, SDBS, n.d. [online] Available at: https://sdbs.db.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi [Accessed 6 October 2021].