Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Thursday 5 November 2020 (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]**.

8820 – 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			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 number of carbon atoms in 12 g of ethanoic acid CH_3COOH, $M_r = 60$?

A. 0.20

B. 2.0

C. 1.2×10^{23}

D. 2.4×10^{23}

2. Which of these molecular formulae are also empirical formulae?

I. C_2H_6O

II. $C_2H_4O_2$

III. C_5H_{12}

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

3. Which volume of ethane gas, in cm^3, will produce 40 cm^3 of carbon dioxide gas when mixed with 140 cm^3 of oxygen gas, assuming the reaction goes to completion?

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

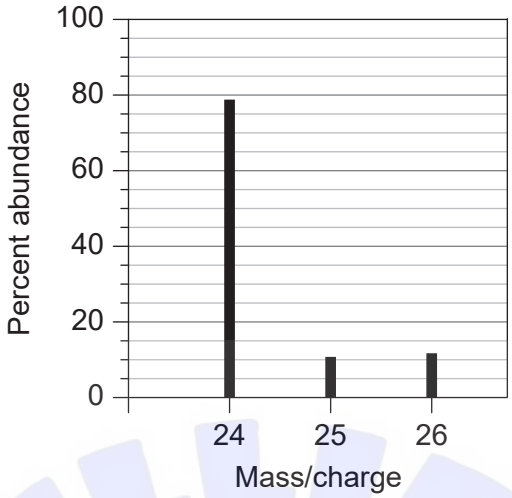
A. 10

B. 20

C. 40

D. 80

4. What is the relative atomic mass, A_r, of an element with this mass spectrum?



A. 24.0

B. 24.3

C. 24.9

D. 25.0

5. Which element is in group 13?

	Ionization energy / kJ mol^{-1}			
	1st	**2nd**	**3rd**	**4th**
A.	789	1580	3230	4360
B.	578	1820	2750	11 600
C.	738	1450	7730	10 500
D.	496	4560	6910	9540

6. What is the correct trend going down groups 1 **and** 17?

A. Melting points increase

B. Boiling points decrease

C. Electronegativities increase

D. Ionization energies decrease

7. Which oxide will dissolve in water to give the solution with the lowest pH?

A. P_4O_{10}

B. SiO_2

C. Al_2O_3

D. MgO

8. Which of these statements are correct?

I. Zinc is **not** a transition element.

II. Ligands are Lewis bases.

III. Manganese(II) chloride is paramagnetic.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which of these species contains the shortest carbon to oxygen bond length?

A. $CH_3CH_2O^-$

B. CH_3CH_2OH

C. CH_3COO^-

D. CH_3COOH

10. Which molecule is most polar?

A. CHF_3

B. CF_4

C. $CClF_3$

D. CCl_4

11. Which combination correctly describes the geometry of BrF_4^-?

	Electron domain geometry around Br	Molecular geometry around Br
A.	Octahedral	Tetrahedral
B.	Tetrahedral	Square planar
C.	Octahedral	Square planar
D.	Tetrahedral	Tetrahedral

12. Which series shows the correct order of metallic bond strength from strongest to weakest?

A. Na > K > Rb > Mg

B. Mg > Rb > K > Na

C. Rb > K > Na > Mg

D. Mg > Na > K > Rb

13. Which statement is correct?

A. O_3 bond dissociation occurs at a longer wavelength of light than O_2 bond dissociation.

B. O_3 bond dissociation occurs at a higher energy than O_2 bond dissociation.

C. O_3 bond lengths are shorter than O_2 bond lengths.

D. O_3 bond dissociation occurs at a higher frequency of light than O_2 bond dissociation.

14. Which equation shows the enthalpy of formation, ΔH_f, of ethanol?

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

B. $4C(s) + 6H_2(g) + O_2(g) \rightarrow 2C_2H_5OH(g)$

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

D. $4C(s) + 6H_2(g) + O_2(g) \rightarrow 2C_2H_5OH(l)$

15. Which statements about bond strength and activation energy are correct for this reaction?

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

	Relative bond strength	Relative magnitude of activation energy, E_a
A.	products < reactants	forward > reverse
B.	products > reactants	forward < reverse
C.	products > reactants	forward > reverse
D.	products < reactants	forward < reverse

16. Which combination gives the standard hydration enthalpy of $Na^+(g)$?

	kJ mol^{-1}
$\Delta H^{\ominus}$ lattice NaCl (s)	+790
$\Delta H^{\ominus}$ solution NaCl (s)	+4
$\Delta H^{\ominus}$ hydration $Cl^-(g)$	–359

A. $4 + 359 + 790$

B. $4 + 359 - 790$

C. $-4 - 359 + 790$

D. $4 - 359 + 790$

17. Which reaction becomes more spontaneous as temperature increases?

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

B. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

C. $3CO_2(g) + 4H_2O(g) \rightarrow C_3H_8(g) + 5O_2(g)$

D. $SO_2(g) + H_2O_2(l) \rightarrow H_2SO_4(l)$

18. Which apparatus can be used to monitor the rate of this reaction?

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

I. A pH meter

II. A gas syringe

III. A colorimeter

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

19. Which change does **not** increase the rate of this reaction?

$$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$$

A. Increasing the particle size of the $CuCO_3$

B. Increasing the temperature

C. Increasing the concentration of $H_2SO_4(aq)$

D. Stirring the reaction mixture

20. What are the units of the rate constant, k, if the rate equation is Rate $= k[A][B]^2$?

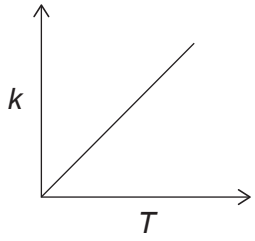
A. $mol\,dm^{-3}\,s^{-1}$

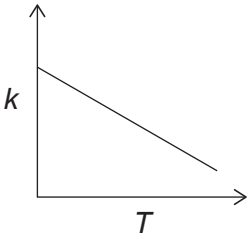
B. $dm^3\,mol^{-1}\,s^{-1}$

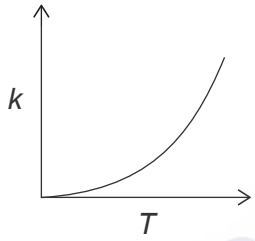
C. $dm^6\,mol^{-2}\,s^{-1}$

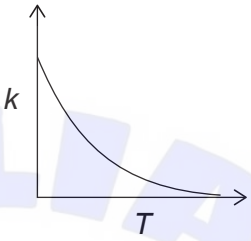
D. $dm^9\,mol^{-3}\,s^{-1}$

21. Which graph represents the relationship between the rate constant, *k*, and temperature, *T*, in kelvin?

A. 

B. 

C. 

D. 

22. What is correct when temperature increases in this reaction at equilibrium?

$$2NOCl\,(g) \rightleftharpoons 2NO\,(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +75.5\,kJ$$

	Position of equilibrium	**Equilibrium constant, K_c**
A.	Shifts left	Unchanged
B.	Shifts left	Decreases
C.	Shifts right	Unchanged
D.	Shifts right	Increases

23. Which statement is correct for a spontaneous reaction?

	$\Delta G^{\ominus}$	K_c
A.	negative	>1
B.	negative	<1
C.	positive	<1
D.	positive	>1

24. Which of these oxides contribute to acid deposition?

I. SO_2
II. NO_2
III. CO_2

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

25. Which of these acids has the weakest conjugate base?

A. HCl

B. CH_3COOH

C. NH_4Cl

D. C_6H_5COOH

26. Which species is a Lewis acid but **not** a Brønsted–Lowry acid?

A. Cu^{2+}

B. NH_4^+

C. Cu

D. CH_3COOH

27. What is the pH of an ammonia solution that has $[OH^-] = 1 \times 10^{-4}\,mol\,dm^{-3}$?

A. 4.0

B. 8.0

C. 10.0

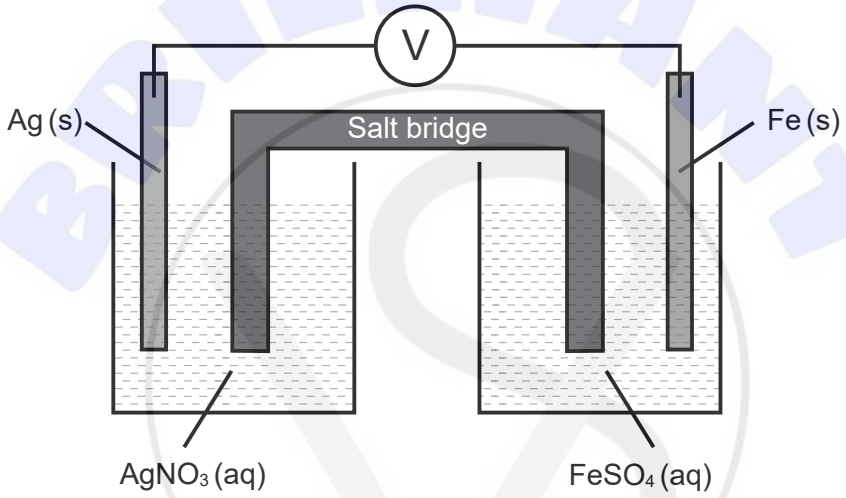
D. 12.0

28. What are the oxidation states of oxygen?

	O_2	OF_2	H_2O_2
A.	–2	–2	–2
B.	0	–2	–1
C.	0	+2	–1
D.	–2	+2	–2

29. Iron is a stronger reducing agent than silver.

What is correct when this voltaic cell is in operation?



	Anode (negative electrode)	Cathode (positive electrode)	Direction of electron flow in wire
A.	Ag	Fe	right to left
B.	Ag	Fe	left to right
C.	Fe	Ag	left to right
D.	Fe	Ag	right to left

30. Which conditions deposit the greatest mass of copper when solutions containing copper ions are electrolysed for 10 minutes?

	Current / A	Ionic charge on copper ion
A.	5.0	2+
B.	2.5	2+
C.	2.5	1+
D.	5.0	1+

31. Which statement is correct when a zinc spoon is electroplated with silver?

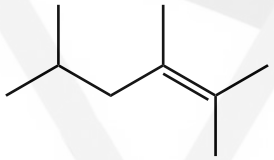
A. The cathode (negative electrode) is made of silver.

B. The anode (positive electrode) is the zinc spoon.

C. The anode (positive electrode) is made of silver.

D. The electrolyte is zinc sulfate solution.

32. What is the IUPAC name of this molecule?



A. 1,1,2,4-tetramethylpent-1-ene

B. 2,4,5-trimethylhex-4-ene

C. 2,4,5,5-tetramethylpent-4-ene

D. 2,3,5-trimethylhex-2-ene

33. Which molecule will decolorize bromine water in the dark?

A. cyclohexane

B. hexane

C. hex-1-ene

D. hexan-1-ol

34. Which molecule can be oxidized to a carboxylic acid by acidified potassium dichromate(VI)?

A. Propan-1-ol

B. Propan-2-ol

C. 2-methylpropan-2-ol

D. Propanone

35. Which is the electrophile in the nitration of benzene?

A. HNO_3

B. NO_2^+

C. NO_2^-

D. NH_4^+

36. What will be the major product in the reaction between but-1-ene and HBr?

A. 2-bromobut-1-ene

B. 1-bromobut-1-ene

C. 2-bromobutane

D. 1-bromobutane

37. Which molecule has an enantiomer?

A. $CH_3CH_2CH(OH)CH_2CH_3$

B. $CH_2(OH)CH_2CH_2CH{=}CH_2$

C. $CH_3CH_2CH_2CH{=}CHBr$

D. $CH_3CHBrCH_2CH_2CH_3$

38. A student obtained the following data to calculate q, using $q = mc\Delta T$.

$$m = 20.0\,\text{g} \pm 0.2\,\text{g}$$

$$\Delta T = 10\,^{\circ}\text{C} \pm 1\,^{\circ}\text{C}$$

$$c = 4.18\,\text{J g}^{-1}\text{K}^{-1}$$

What is the percentage uncertainty in the calculated value of q?

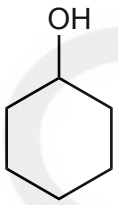
A. 0.2

B. 1.2

C. 11

D. 14

39. What is the index of hydrogen deficiency (IHD) in cyclohexanol?



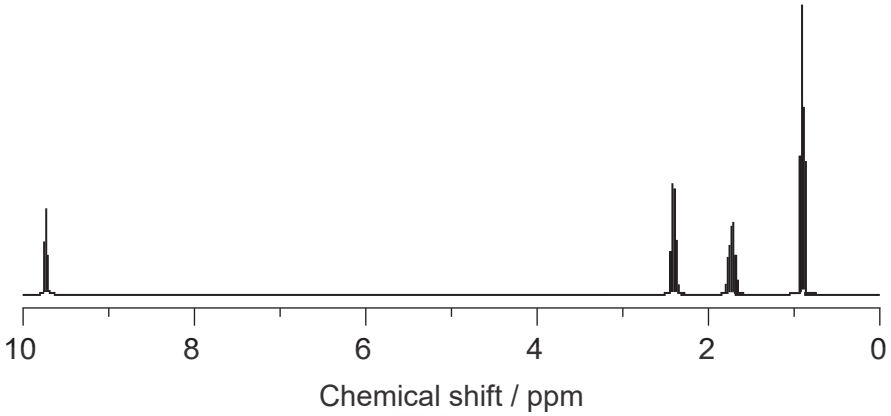
A. 0

B. 1

C. 2

D. 3

40. Which compound with the molecular formula C_4H_8O has this high resolution ^1H NMR?



A. but-3-en-2-ol, $CH_2{=}CHCH(OH)CH_3$

B. butanal, $CH_3CH_2CH_2CHO$

C. butanone, $CH_3COCH_2CH_3$

D. but-3-en-1-ol, $CH_2{=}CHCH_2CH_2OH$

References:

40. From: libretexts.org. Courtesy of Chris Schaller, Professor (Chemistry) at College of Saint Benedict/Saint John's University.