Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Thursday 14 May 2015 (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]**.

2215–6107

The Periodic Table

1	2											3	4	5	6	7	0
1 **H** 1.01																	2 **He** 4.00
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
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)															

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1. 4.0 g of solid sodium hydroxide is added to 0.10 dm^3 of 1.0 mol dm^{-3} aqueous sulfuric acid.

$$2NaOH(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Which statement is correct?

A. Neither reactant is in excess.

B. 0.10 mol Na_2SO_4 is formed.

C. Excess H_2SO_4 remains in solution.

D. Excess NaOH remains in solution.

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

A. CH_4

B. C_2H_4

C. C_4H_{10}

D. C_6H_6

3. Which solution contains the biggest amount, in mol, of chloride ions?

A. 20 cm^3 of 0.50 mol dm^{-3} NH_4Cl

B. 60 cm^3 of 0.20 mol dm^{-3} $MgCl_2$

C. 70 cm^3 of 0.30 mol dm^{-3} NaCl

D. 100 cm^3 of 0.30 mol dm^{-3} $ClCH_2COOH$

4. Ultraviolet radiation has a shorter wavelength than infrared radiation. How does the frequency and energy of ultraviolet radiation compare with infrared radiation?

	Frequency	Energy
A.	higher	higher
B.	higher	lower
C.	lower	higher
D.	lower	lower

5. The first ionization energies (in $kJ\,mol^{-1}$) of five **successive** elements in the periodic table are:

1314, 1681, 2081, 496 and 738

What could these elements be?

A. d-block elements

B. The last two elements of one period and the first three elements of the next period

C. The last three elements of one period and the first two elements of the next period

D. The last five elements of a period

6. What is the total number of valence electrons in CH_3COO^-?

A. 16

B. 22

C. 23

D. 24

7. What is the definition of the term *first ionization energy*?

A. The energy released when one mole of electrons is removed from one mole of gaseous atoms.

B. The energy required to remove one mole of electrons from one mole of gaseous atoms.

C. The energy released when one mole of gaseous atoms gains one mole of electrons.

D. The energy required to add one mole of electrons to one mole of gaseous atoms.

8. Which statements are correct about the complex $[Cu(NH_3)_2Cl_2]$?

I. Oxidation state of copper is +2.

II. Ammonia is a ligand.

III. Chloride ions act as Lewis acids.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which molecules react to form a dative covalent (coordinate) bond?

A. CH_4 and NH_3

B. C_2H_2 and Cl_2

C. NH_3 and HF

D. Cl_2 and HF

10. The following compounds have similar molar masses:

CH_3CH_2COOH, $CH_3CH_2CH_2CH_2OH$ and $CH_3CH_2CH_2CH_2CH_3$

What is the order of **increasing** boiling points?

A. $CH_3CH_2CH_2CH_2OH < CH_3CH_2COOH < CH_3CH_2CH_2CH_2CH_3$

B. $CH_3CH_2COOH < CH_3CH_2CH_2CH_2CH_3 < CH_3CH_2CH_2CH_2OH$

C. $CH_3CH_2COOH < CH_3CH_2CH_2CH_2OH < CH_3CH_2CH_2CH_2CH_3$

D. $CH_3CH_2CH_2CH_2CH_3 < CH_3CH_2CH_2CH_2OH < CH_3CH_2COOH$

11. Which substance has the following properties?

- Low melting point
- Very soluble in water
- Does not conduct electricity when molten

A. Glucose, $C_6H_{12}O_6$

B. Silicon dioxide, SiO_2

C. Sodium chloride, NaCl

D. Tetrachloromethane, CCl_4

12. What is correct for PCl_5?

	Shape	Bond angle(s)
A.	Octahedral	90° and 180°
B.	Trigonal pyramidal	107°
C.	Square pyramidal	90° and 180°
D.	Trigonal bipyramidal	90°, 120° and 180°

13. Which molecules have sp^2 hybridization?

I. C_2H_4

II. C_4H_{10}

III. C_6H_6

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

14. The same amount of heat energy is added to 1.00 g of each substance.

Substance	Specific heat capacity / $J\,g^{-1}\,K^{-1}$
Copper	0.39
Aluminium	0.90
Sodium chloride	0.90
Water	4.18

Which statement is correct if all the substances are at the same temperature before the heat energy is added?

A. Copper will reach the highest temperature.

B. Water will reach the highest temperature.

C. All four substances will reach the same temperature.

D. Aluminium will reach a higher temperature than sodium chloride.

15. The heat change in a neutralization reaction can be determined by mixing equal volumes of HCl (aq) and NaOH (aq) of the same concentration in a glass beaker. The maximum temperature change is recorded using an alcohol thermometer.

What is the biggest source of error in this experiment?

A. Heat absorbed by the glass thermometer

B. Random error in the thermometer reading

C. Heat loss to the surroundings

D. Systematic error in measuring the volumes of HCl (aq) and NaOH (aq) using burettes

16. Which equation represents the standard enthalpy of formation of liquid methanol?

A. $C(g) + 2H_2(g) + \frac{1}{2}O_2(g) \rightarrow CH_3OH(l)$

B. $C(g) + 4H(g) + O(g) \rightarrow CH_3OH(l)$

C. $C(s) + 4H(g) + O(g) \rightarrow CH_3OH(l)$

D. $C(s) + 2H_2(g) + \frac{1}{2}O_2(g) \rightarrow CH_3OH(l)$

17. Which species are arranged in order of **increasing** entropy?

A. $C_3H_8(g) < CH_3OH(l) < Hg(l) < Na(s)$

B. $CH_3OH(l) < C_3H_8(g) < Hg(l) < Na(s)$

C. $Na(s) < Hg(l) < CH_3OH(l) < C_3H_8(g)$

D. $Na(s) < Hg(l) < C_3H_8(g) < CH_3OH(l)$

18. Which combination of ΔH and ΔS values corresponds to a non-spontaneous reaction at all temperatures?

	ΔH	ΔS
A.	–	–
B.	+	–
C.	–	+
D.	+	+

19. Nitrogen gas reacts with hydrogen gas according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ$$

Why is the rate of reaction slow at room temperature?

A. The activation energy of the forward reaction is high.

B. The activation energy of the forward reaction is low.

C. The equilibrium constant is very small.

D. The rate of the reverse reaction is greater than the rate of the forward reaction.

20. Which statement about a first-order reaction is correct?

A. The reactant concentration decreases linearly with time.

B. The reactant concentration decreases exponentially with time.

C. The rate of reaction remains constant as the reaction proceeds.

D. The rate of reaction increases exponentially as the reaction proceeds.

21. Consider the rate expression:

$$\text{Rate} = k[\text{X}]\,[\text{Y}]$$

Which change decreases the value of the rate constant, *k*?

A. Increase in the reaction temperature

B. Decrease in the reaction temperature

C. Increase in the concentration of X and Y

D. Decrease in the concentration of X and Y

22. Carbon monoxide and water react together in the industrial production of hydrogen gas.

$$\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$$

What is the impact of decreasing the volume of the equilibrium mixture at a constant temperature?

A. The amount of $\text{H}_2(\text{g})$ remains the same but its concentration decreases.

B. The forward reaction is favoured.

C. The reverse reaction is favoured.

D. The value of K_c remains unchanged.

23. Which factors do **not** affect the vapour pressure of a liquid in equilibrium with its vapour in a closed container?

I. Volume of container

II. Volume of liquid

III. Temperature

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

24. Which gas in the atmosphere causes the pH of unpolluted rain to be approximately 6?

A. Carbon dioxide

B. Sulfur dioxide

C. Oxygen

D. Nitrogen

25. Which compound is a strong acid?

A. NH_3

B. HNO_3

C. H_2CO_3

D. CH_3COOH

26. The forward reaction of this equilibrium is endothermic.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25\,^\circ C$$

What is correct about water at 50 °C?

A. $[H^+] > [OH^-]$

B. $[H^+] < [OH^-]$

C. $pH < 7.0$

D. $pH = 7.0$

27. Which equation represents a reaction for which a base dissociation constant expression, K_b, can be written?

A. $CH_3COOH(aq) + NH_3(aq) \rightleftharpoons CH_3COO^-(aq) + NH_4^+(aq)$

B. $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$

C. $HCN(aq) + OH^-(aq) \rightleftharpoons CN^-(aq) + H_2O(l)$

D. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

28. An equal amount of each of the following salts is added separately to the same volume of water. Which salt will have the greatest effect on the pH of water?

A. $Al(NO_3)_3$

B. Na_2SO_4

C. RbCl

D. KBr

29. Which mixture will form a buffer in aqueous solution?

A. $0.10\,mol\,NH_3 + 0.20\,mol\,HCl$

B. $0.10\,mol\,NH_3 + 0.20\,mol\,NaOH$

C. $0.10\,mol\,NaOH + 0.20\,mol\,KCl$

D. $0.20\,mol\,NH_3 + 0.10\,mol\,HCl$

30. Which represents a redox reaction?

A. $NaH(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$

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

C. $CuCl_2(aq) + K_2S(aq) \rightarrow CuS(s) + 2KCl(aq)$

D. $HCl(aq) + NH_3(aq) \rightarrow NH_4^+Cl^-(aq)$

31. Two half-cells are connected via a salt bridge to make a voltaic cell. Which statement about this cell is correct?

A. Oxidation occurs at the positive electrode (cathode).

B. It is also known as an electrolytic cell.

C. Ions flow through the salt bridge.

D. It requires a power supply to operate.

32. Which signs are correct for a spontaneous redox reaction?

	Standard electrode potential, $E^{\ominus}$	**Standard free energy change, $\Delta G^{\ominus}$**
A.	+	–
B.	–	+
C.	–	–
D.	+	+

33. Consider the standard electrode potentials:

$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s) \qquad E^{\ominus} = -0.45\,V$$

$$\tfrac{1}{2}Cl_2(g) + e^- \rightleftharpoons Cl^-(aq) \qquad E^{\ominus} = +1.36\,V$$

What is the standard cell potential, in V, for the reaction?

$$Cl_2(g) + Fe(s) \rightarrow 2Cl^-(aq) + Fe^{2+}(aq)$$

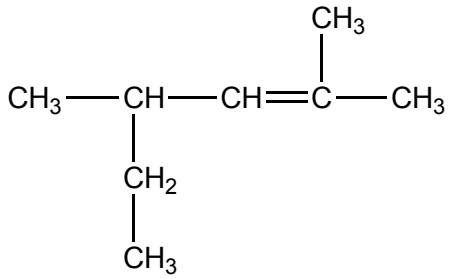
A. +0.91

B. +1.81

C. +2.27

D. +3.17

34. Applying IUPAC rules, what is the name of the compound?



A. 1-ethyl-1,3-dimethylbut-2-ene

B. 2-ethyl-4-methylpent-3-ene

C. 2-methyl-4-ethylpent-3-ene

D. 2,4-dimethylhex-2-ene

35. What is the product of the addition of chlorine, Cl_2, to propene, C_3H_6?

A. 1,1-dichloropropane

B. 2,2-dichloropropane

C. 1,2-dichloropropane

D. 1,3-dichloropropane

36. What should be changed to alter the rate of nucleophilic substitution of tertiary halogenoalkanes?

A. The nucleophile

B. The concentration of the nucleophile

C. The concentration of the tertiary halogenoalkane

D. The size of the reaction flask

37. Which compound could be **X** in the two-stage reaction pathway?

$$C_2H_6 \rightarrow \mathbf{X} \rightarrow C_2H_5NH_2$$

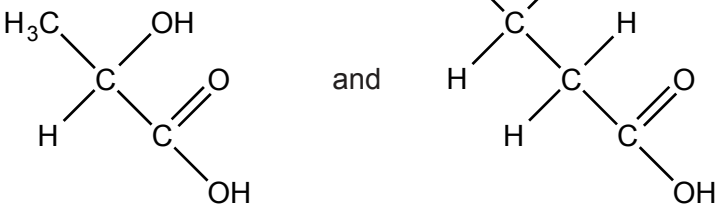
A. C_2H_4

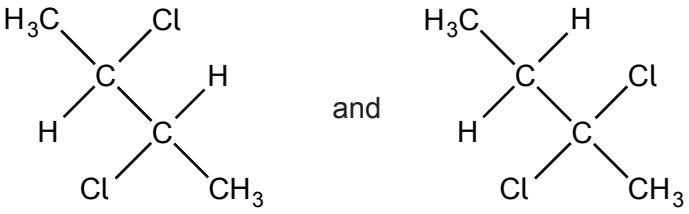
B. C_2H_5Cl

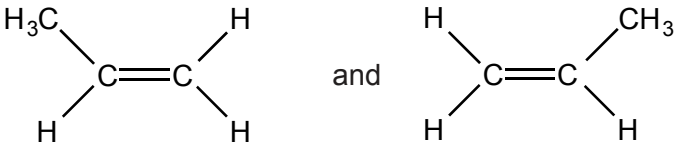
C. $C_2H_4Cl_2$

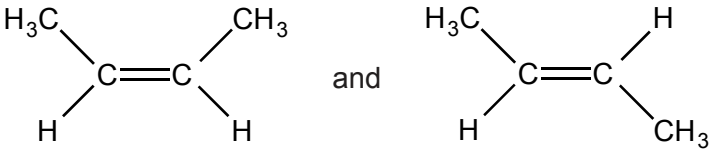
D. C_2H_5OH

38. Which pair are geometric isomers?

A. 

B. 

C. 

D. 

39. Which reagent(s) can be used to convert CH_3CH_2CN to $CH_3CH_2CH_2NH_2$?

A. H_2 only

B. H_2O only

C. H_2 in the presence of Ni

D. H_2O in the presence of H^+

40. A student weighs a standard 70.00 g mass five times using the same balance. Each time she obtains a reading of 71.20 g. Which statement is correct about the precision and accuracy of the measurements?

A. Precise and accurate

B. Precise but inaccurate

C. Accurate but not precise

D. Neither accurate nor precise