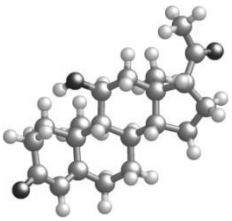


Chem!stry

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

Chemistry Olympiad Training for Secondary School Level – Part Two

1. Study the three chemical reactions shown below:

$$H^+ + :NH_3 \rightarrow (H:NH_3)^+$$

$$AlCl_3 + :Cl_2 \rightarrow (Cl:AlCl_3)^- + Cl^+$$

$$BF_3 + :NH_3 \rightarrow F_3B:NH_3$$

What do all three reactions have in common?

A They are all precipitation reactions.

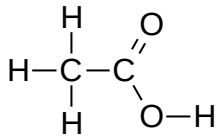
B They are all redox reactions.

C They are reactions of Lewis acids and bases.

D They are reactions of Brønsted-Lowry acids and bases.

2. Which one of the four carboxylic acids shown below is the strongest acid?

A



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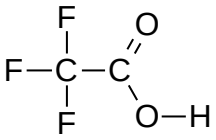
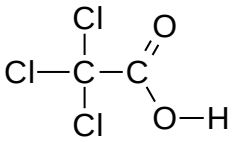
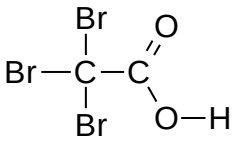


C



D



3. The enthalpy change, under standard conditions, for which one of the reactions below would be equal to the ΔH°_f of NaOH (s)?

A $Na(s) + H_2O(l) \rightarrow NaOH(s) + {}^1/_2H_2(g)$

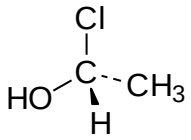
B $Na(s) + {}^1/_2O_2(g) + {}^1/_2H_2(g) \rightarrow NaOH(s)$

C $Na(s) + {}^1/_2H_2O_2(l) \rightarrow NaOH(s)$

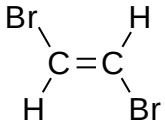
D $Na^+(aq) + OH^-(aq) \rightarrow NaOH(s)$

4. Which one of the following organic compounds will rotate plane polarised light?

A



B



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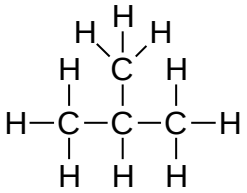

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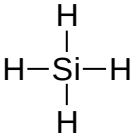
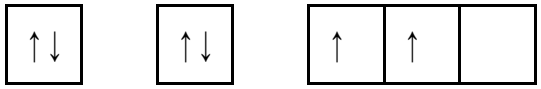


5. Which one of the following electronic arrangements shows sp^3 hybridisation in carbon?

A



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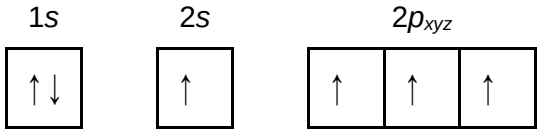
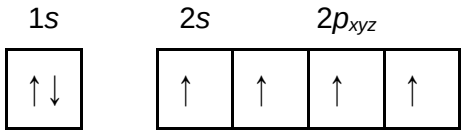
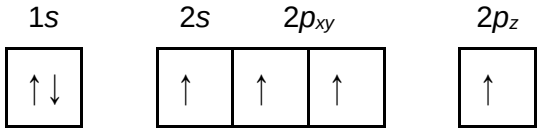


C



D



6. Which calcium compound is not appreciably more soluble in 0.1 mol dm^{-3} hydrochloric acid than it is in pure water?

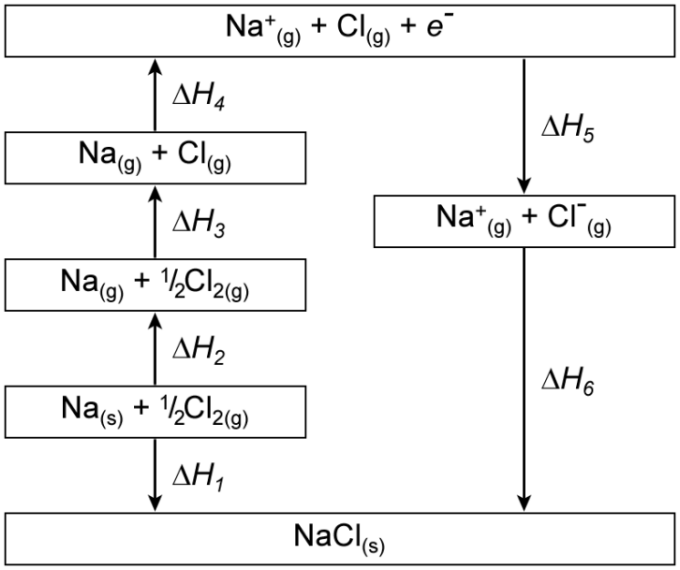
A Limestone, $CaCO_3$

B Slaked lime, $Ca(OH)_2$

C Gypsum, $CaSO_4 \cdot 2H_2O$

D Hydroxyapatite, $Ca_5(OH)(PO_4)_3$

7. The Born-Haber cycle shown below represents the formation of sodium chloride from sodium and chlorine:



Which of the enthalpy changes (ΔH) is correctly paired with its description?

A ΔH_1 is the enthalpy change of combustion for sodium chloride.

B ΔH_4 is the first electron affinity for sodium.

C ΔH_5 is the first ionisation energy for chlorine.

D ΔH_6 is the lattice enthalpy for sodium chloride.

8. At the molecular level, the factor that determines whether a substance will be a solid, liquid or gas is the balance between the…

A Kinetic energies of the molecules and their intermolecular forces.

B Potential energies of the molecules and their intermolecular forces.

C Kinetic energies of the molecules and their intramolecular forces.

D Potential energies of the molecules and their intramolecular forces.

9. What is the oxidation state of C in methanal, CH_2O?

A –2 **B** 0

C +2 **D** +4

10. Which molecule is correctly matched with its shape as predicted by as predicted by valence shell electron pair repulsion theory (VSEPRT)?

A CH_4 octahedral

B NH_3 linear

C PCl_5 trigonal bipyramidal

D SF_6 tetrahedral

11. A sulfur atom in the ground state has the electronic configuration:

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

How many orbitals are occupied by at least one electron?

A 5 **B** 9

C 11 **D** 16

12. The molecules in a sample of pure liquid dichloromethane, CH_2Cl_2, experience which of the following intermolecular forces:

I van der Waals forces

II dipole-dipole forces

III Hydrogen bonds

A **I** only **B** **II** only

C **I** and **II** only **D** **I**, **II** and **III**

13. What is the equilibrium expression for the reaction given below?

$$2C(s) + O_2(g) \rightleftharpoons 2CO(s)$$

A $K = \dfrac{2[CO]}{2[C] \times [O_2]}$ **B** $K = \dfrac{2[CO]}{[O_2]}$

C $K = \dfrac{[CO]^2}{[C]^2 \times [O_2]}$ **D** $K = \dfrac{[CO]^2}{[O_2]}$

14. Consider the following reactions:

I $2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$

II $2IBr(g) \rightarrow I_2(s) + Br_2(l)$

For which reaction is $\Delta S^\circ < 0$?

A **I** only **B** **II** only

C Both **I** and **II** **D** Neither **I** nor **II**

15. Given chemical equations for these reactions:

$$S(s) + O_2(g) \rightarrow SO_2(g) \qquad \Delta H° = -296.8 \text{ kJ mol}^{-1}$$

$$H_2(g) + {}^1/_2O_2(g) \rightarrow H_2O(l) \qquad \Delta H° = -285.8 \text{ kJ mol}^{-1}$$

$$H_2(g) + S(s) \rightarrow H_2S(g) \qquad \Delta H° = -20.6 \text{ kJ mol}^{-1}$$

What is the value of ΔH for the reaction given below?

$$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$$

A –603.2 kJ mol^{-1} **B** –562.0 kJ mol^{-1}

C –1206.4 kJ mol^{-1} **D** –1124.0 kJ mol^{-1}

16. What property of the oxygen atom is represented by the equation $O(g) + e^- \rightarrow O^-(g)$?

A Electronegativity.

B First electron affinity.

C First ionisation energy.

D Lattice energy.

17. Which one of the following isoelectronic species has the largest atomic radius?

A K^+ **B** Ca^{2+}

C P^{3-} **D** S^{2-}

18. Chemical **A** reacts with chemical **B** to form chemical **C** according to the reaction given below:

$$\mathbf{A}(g) + \mathbf{B}(g) \rightarrow \mathbf{C}(g)$$

The data below was obtained for the reaction between **A** and **B**. What is the rate equation for this reaction?

Experiment	[**A**] / mol dm^{-3}	[**B**] / mol dm^{-3}	Initial Rate of Reaction / mol dm^{-3} s^{-1}
1	0.10	0.10	6.5×10^{-5}
2	0.20	0.10	2.6×10^{-4}
3	0.10	0.20	6.5×10^{-5}

A Rate = $k \times [A]$ **B** Rate = $k \times [A] \times [B]$

C Rate = $k \times [A]^2$ **D** Rate = $k \times [A]^2 \times [B]$

19. Values for some standard electrode potentials ($E°$) are given in the table below:

Half-reaction	$E°$ / V
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.760
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	–0.744
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.409

Use the $E°$ values in the table to determine which one of the following reactions will give the highest potential difference in a simple voltaic cell.

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

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

C $Zn^{2+}(aq) + Fe(s) \rightarrow Zn(s) + Fe^{2+}(aq)$

D $Zn(s) + Fe^{2+}(aq) \rightarrow Zn^{2+}(aq) + Fe(s)$

20. The ideal gas equation is given below:

$$PV = nRT$$

$$R = \text{gas constant} = 8.314\ JK^{-1}mol^{-1}$$

$$n = \text{amount of gas / mol}$$

What volume does 64.0 g of oxygen gas occupy at a pressure of 101 000 pa and a temperature of 100 °C?

Note: $A_r[O] = 16.0$

A 0.0165 m^3 **B** 0.0614 m^3

C 0.123 m^3 **D** 0.0329 m^3

The Periodic Table of the Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group 0
							1 H hydrogen 1										4 He helium 2
7 Li lithium 3	9 Be beryllium 4											11 B boron 5	12 C carbon 6	14 N nitrogen 7	16 O oxygen 8	19 F fluorine 9	20 Ne neon 10
23 Na sodium 11	24 Mg magnesium 12											27 Al aluminium 13	28 Si silicon 14	31 P phosphorus 15	32 S sulfur 16	35.5 Cl chlorine 17	40 Ar argon 18
39 K potassium 19	40 Ca calcium 20	45 Sc scandium 21	48 Ti titanium 22	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	64 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	89 Y yttrium 39	91 Zr zirconium 40	93 Nb niobium 41	96 Mo molybdenum 42	– Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La lanthanum 57 *	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	– Po polonium 84	– At astatine 85	– Rn radon 86
– Fr francium 87	– Ra radium 88	– Ac actinium 89 †															

*58-71 Lanthanoid series

†90-103 Actinoid series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	– Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	162 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	– Pa protactinium 91	238 U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lr lawrencium 103

Key

a
X
b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

Answers

1. **D**
2. **B**
3. **B**
4. **A**
5. **C**
6. **C**
7. **D**
8. **A**
9. **B**
10. **C**
11. **B**
12. **C**
13. **D**
14. **B**
15. **D**
16. **B**
17. **C**
18. **C**
19. **D**
20. **B**