**IB Chemistry – HL**

**Topic 3 Questions**

**1.** Which of the following salts form coloured solutions when dissolved in water?

I. ScCl3

II. FeCl3

III. NiCl2

IV. ZnCl2

A. I and II only

B. II and III only

C. III and IV only

D. I, II, III and IV

(Total 1 mark)

**2.** Which is an essential feature of a ligand?

A. a negative charge

B. an odd number of electrons

C. the presence of two or more atoms

D. the presence of a non-bonding pair of electrons

(Total 1 mark)

**3.** Which equation represents the third ionization energy of an element M?

A. M+(g)  M4+(g) + 3e–

B. M2+(g)  M3+(g) + e–

C. M(g)  M3+(g) + 3e–

D. M3+(g)  M4+(g) + e–

(Total 1 mark)

**4.** Which electrons are lost by an atom of iron when it forms the Fe3+ ion?

A. One s orbital electron and two d orbital electrons

B. Two s orbital electrons and one d orbital electron

C. Three s orbital electrons

D. Three d orbital electrons

(Total 1 mark)

**5.** Which properties are typical of d-block elements?

I. complex ion formation

II. catalytic behaviour

III. colourless compounds

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

(Total 1 mark)

**6.** Which combination of ion charge and ion size produces the greatest lattice enthalpy?

A. High charge, large size

B. High charge, small size

C. Low charge, small size

D. Low charge, large size

(Total 1 mark)

**7.** Which salts form coloured solutions when dissolved in water?

I. FeCl3  
II. NiCl2  
III. ZnCl2

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

(Total 1 mark)

**8.** Which combination is correct for the complex ion in [Co(NH3)4(H2O)Cl]Br?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Oxidation state of cobalt** | **Shape of the complex ion** | **Overall charge of the complex ion** |
| A. | +2 | Octahedral | +2 |
| B. | +3 | Octahedral | –1 |
| C. | +2 | Octahedral | +1 |
| D. | +2 | Tetrahedral | +1 |

(Total 1 mark)

**9.** Define the term *ligand*. Cu2+(aq) reacts with ammonia to form the complex ion  
[Cu(NH3)4]2+. Explain this reaction in terms of an acid-base theory, and outline the bonding in the complex ion formed between Cu2+ and NH3.

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(Total 4 marks)

**10.** By reference to the structure and bonding in the compounds NaCl and SiCl4

(i) state and explain the differences in conductivity in the liquid state.

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(3)

(ii) predict an approximate pH value for a solution formed by adding each compound separately to water.

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(4)

(Total 7 marks)

**11.** Two characteristics of the d-block (transition) elements are that they exhibit variable oxidation states and form coloured compounds.

(i) State **two** possible oxidation states for iron and explain these in terms of electron arrangements.

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(2)

(ii) Explain why many compounds of d-block (transition) elements are coloured.

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(3)

(Total 5 marks)

**12.** Silicon tetrachloride, SiCl4, reacts with water to form an acidic solution.

(i) Explain why silicon tetrachloride has a low melting point.

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(2)

(ii) Write an equation for the reaction of silicon tetrachloride with water.

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(1)

(Total 3 marks)

**13.** Magnesium chloride and silicon(IV) chloride have very different properties.

(i) Give the formula and physical state at room temperature of each chloride.

(2)

(ii) State the conditions under which, if at all, each chloride conducts electricity.

(2)

(iii) Each chloride is added to water in separate experiments. Suggest an approximate pH value for the solution formed, and write an equation for any reaction that occurs.

(3)

(Total 7 marks)

**14.** The elements in the d-block in the periodic table have several characteristics in common.

(i) Give the electronic configuration of Ni2+.

(1)

(ii) Explain what is meant by a ligand, and describe the type of bond formed between a ligand and a d-block element.

(2)

(iii) Determine the oxidation numbers of copper in the species

[Cu(NH3)4]2+ and [CuCl4]2–

(2)

(iv) Explain why the species in (iii) are coloured.

(3)

(v) Identify the d-block element used as a catalyst in the Haber process and write an equation for the reaction occurring.

(2)

(Total 10 marks)

**15.** (i) Explain why complexes of Zn2+ are colourless whereas complexes containing Cu2+ are coloured.

(3)

(ii) Give the formula and describe the shape of the complex ion formed between Fe3+ and the ligand CN–.

(2)

(Total 5 marks)

**16.** Consider the transition metal complex, K3[Fe(CN)6].

(i) Define the term *ligand*, and identify the ligand in this complex.

(1)

(ii) Write the full electron configuration and draw the orbital diagram of iron in its oxidation state in this complex, and hence, determine the number of unpaired electrons in this state.

(3)

(iii) Explain why many transition metal d-block complexes are coloured.

(3)

(Total 7 marks)

**17.** By reference to the structure and bonding in NaCl and SiCl4:

(i) State and explain the differences in electrical conductivity in the liquid state.

(3)

(ii) Predict an approximate pH value for the solutions formed by adding each compound separately to water. Explain your answer.

(4)

(Total 7 marks)

**18.** Elements with atomic number 21 to 30 are d-block elements.

(a) Identify which of these elements are **not** considered to be typical transition elements.

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(1)

(b) Complex ions consist of a central metal ion surrounded by ligands. Define the term *ligand*.

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(2)

(c) Complete the table below to show the oxidation state of the **transition element**.

(3)

|  |  |  |  |
| --- | --- | --- | --- |
| ion | Cr2O72– | [CuCl4]2– | [Fe(H2O)6]3+ |
| oxidation state |  |  |  |

(d) Identify **two** transition elements used as catalysts in industrial processes, stating the process in each case.

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(2)

(e) Apart from the formation of complex ions and apart from their use as catalysts, state **two** other properties of transition elements.

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(2)

(Total 10 marks)

**IB Chemistry – HL**

**Topic 3 Answers**

**1.** B

[1]

**2.** D

[1]

**3.** B

[1]

**4.** B

[1]

**5.** A

[1]

**6.** B

[1]

**7.** A

[1]

**8.** C

[1]

**9.** ligand: a molecule or ion that can bond to a (central) metal ion  
(to form a complex);  
NH3: Lewis base and Cu2+: Lewis acid (*need both for mark*);  
each NH3/ligand donates an electron pair (to Cu2+);  
forming coordinate covalent/dative covalent bond; 4

[4]

**10.** (i) NaCl conducts **and** SiCl4 does not;  
NaCl ionic **and** SiCl4 covalent;  
ions can move in liquid (in NaCl)/*OWTTE*; 3

(ii) NaCl pH = 7;  
salt of strong acid and strong base/Na+ and Cl– not hydrolysed;  
SiCl4 pH = 0 to 3;  
HCl is formed/strong acid formed; 4

[7]

**11.** (i) +2 and +3/Fe2+ and Fe3+;  
both s electrons are lost giving Fe2+ **and** one more d electron is   
also lost to form Fe3+; 2

(ii) presence of unpaired electrons;  
the d orbitals are split into two energy levels;  
electrons move between these energy levels;  
electrons can absorb energy from light of visible wavelength  
/*OWTTE*; 3

Award **[1]** each for any three.

[5]

**12.** (i) van der Waals’ forces (between molecules);

Accept London or dispersion forces or temporary dipole-dipole attractions.

(these forces are) weak/easily overcome; 2

(ii) SiCl4 + 4H2O  Si(OH)4 + 4HCl; 1

Ignore state symbols, accept SiO2.2H2O or H4SiO4 as product.

[3]

**13.** (i) MgCl2 and SiCl4;  
MgCl2 solid and SiCl4 liquid; 2

(ii) MgCl2 (conducts electricity) when molten/dissolved in water;  
SiCl4 does not conduct (under any conditions); 2

(iii) MgCl2 pH value in range 5.0 to 6.9/just under 7;  
SiCl4 pH value in range 0 to 3;  
SiCl4 + 4H2O  Si(OH)4 + 4HCl/SiO2.2H2O + 4HCl; 3

Do not accept SiCl4 + 2H2O  SiO2 + 4HCl.

[7]

**14.** (i) Ni2+ 1s22s22p63s23p63d8 / [Ar]3d8; 1

(ii) species with lone pair of electrons used to bond with the ion;  
co-ordinate bond/dative (covalent) bond; 2

(iii) +2;  
+2; 2

Accept 2+ but not 2 or II.

(iv) d orbitals/sub-levels (in complexes) split (into two sets at different  
energy levels);  
energy difference corresponds to frequency/wavelength of (part of)  
visible light;  
part of visible spectrum absorbed by electrons;  
when they move between energy levels; 3

OWTTE for all of the above.

Award **[1]** each for any two of the last three.

(v) iron;  
N2 + 3H2  2NH3; 2

No penalty for .

[10]

**15.** (i) Zn2+ has full d sub-shell / Zn2+ does not have partially filled d sub-shell/  
Cu2+ has partially filled d sub-shell/orbitals;  
d orbitals are split (into two sets of different energy levels);  
colour due to electron transition between (split) d orbitals; 3

(ii) [Fe(CN)6]3;  
octahedral/suitable diagram; 2

Accept square bipyramidal

[5]

**16.** (i) an ion or molecule, with a lone pair of electrons that coordinates to a metal  
atom or to a metal ion to form a complex/(*OWTTE*) **and** cyanide/CN−; 1

(ii) Fe3+ = 1*s*2, 2*s*2, 2*p*6, 3*s*2, 3*p*6, 3*d*5;

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| [Ar] |  |  |  |  |  | ; |

3*d*5

5 unpaired electrons; 3

(iii) presence of unpaired electrons;  
the d orbitals are split into two energy levels;  
electrons move between these energy levels;  
absorb energy from light of visible wavelength/*OWTTE*; 3 max

Award **[1]** each for any three.

[7]

**17.** (i) NaCl conducts **and** SiCl4 does not;  
NaCl ionic **and** SiCl4 covalent;  
ions can move in liquid (in NaCl); 3

(ii) NaCl pH = 7;  
salt of strong acid and strong base/Na+ and Cl− not hydrolysed;  
SiCl4 pH = 0 to 3;  
HCl is formed/strong acid formed; 4

[7]

**18.** (a) zinc/ Zn; 1

(b) species/neutral molecules/anions which contain a non-bonding pair  
of electrons; able to form coordinate/dative covalent bonds; 2

(c)

|  |  |  |  |
| --- | --- | --- | --- |
| ion | Cr2O72– | 2[CuCl4]2– | [Fe(H2O)6]3+ |
| oxidation state | +6 | +2 | +3 |

Accept 6+, 2+, 3+. If given as 6, 2, 3 or (VI), (II), (III),   
Award **[2]** only. 3

(d) V/V2O5 in the contact process;  
Fe in the Haber process;  
Ni in the conversion of alkenes to alkanes/hydrogenation reactions; 2 max

Award **[1]** each for any two.

Accept any other suitable examples.

(e) variable oxidation states; coloured compounds; 2

Accept any other suitable examples.

[10]