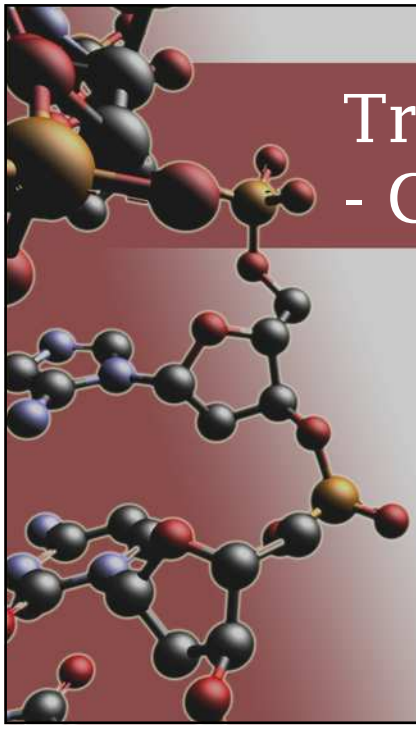
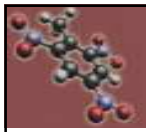


Transition Metals - Characteristics

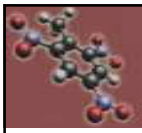
Catalysts
Complex Ions
Coloured Ions
Oxidation States
pH

Author: J R Reid



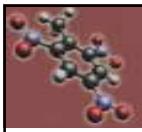
What is a Transition Metal?

1	2	The Transition Metals										13	14	15	16	17	18
H 1																	He 2
Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88	Ac 89															



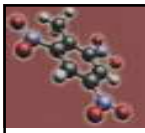
Catalysts

- A catalyst is a chemical that will speed up a reaction without being consumed by the reaction
- A catalytic converter in the exhaust of a car will convert two poisonous gases (NO_2 and CO) into non-toxic gases (N_2 and CO_2) without using up any of the catalyst
- Transition metals make good catalysts. They are actually converted to other substances in the process of the reaction but then they are converted back to their original form by the end of the reaction



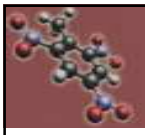
Examples

- Manganese dioxide
  - Reaction: Converting hydrogen peroxide into water and oxygen
- Iron
  - Reaction: The Haber Process
  - The conversion of Nitrogen and Hydrogen gas into Ammonia
  - Importance – Ammonia is used in fertiliser and explosive production
- Vanadium pentoxide
  - Reaction: The Contact Process
  - The conversion of Sulfur dioxide and Oxygen into Sulfur trioxide
  - Importance – Sulfuric acid production for making fertilisers



Complex Ions

- A complex ion is a combination of a positive ion (a transition metal ion normally) and a negatively charged chemical that is associated with it
- The negatively charged particle is called a ligand. It could be charged due to being a anion (negative ion) or a strongly polar molecule
  - Anions – Chloride (Cl^-), Hydroxide (OH^-), Thiocyanide (SCN^-)
  - Polar – Water (H_2O), Ammonia (NH_3)



Naming Complex Ions

- The names for complex ions have three parts
  - First – The number of ligands
  - Second – The name of the ligand
  - Third – The name of the cation (metal) and **its** charge before it became a complex ion
- There's a catch.
  - The numbers are 'coded' e.g. 2 = di
  - The ligands are altered slightly e.g. water = aquo
  - The metals charges are in roman numerals 3 = (III)

The Naming Details

Numbers	
1	
2	di
4	tetra
6	hexa

Ligand		
Chloride	chloro	Cl^-
Hydroxide	hydroxy	OH^-
Thiocyanide	thiocyano	SCN^-
Water	aquo	H_2O
Ammonia	ammine	NH_3

Formula	Name
$Mn(H_2O)_6^{2+}$	hexaaquomanganese(II)
$CuCl_4^{2-}$	tetrachlorocopper(II)

Examples of Complex Ions

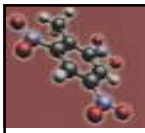
Name	Formula	Colour
thiocyanoiron(III)	$FeSCN^{2+}$	Deep Red
diamminesilver(I)	$Ag(NH_3)_2^+$	Colourless
tetrachlorocopper(II)	$CuCl_4^{2-}$	Yellow
tetraamminecopper(II)	$Cu(NH_3)_4^{2+}$	Deep Blue
tetraamminezinc(II)	$Zn(NH_3)_4^{2+}$	Colourless
tetrahydroxyzinc(II)	$Zn(OH)_4^{2-}$	Colourless
hexaaquoiron(III)	$Fe(H_2O)_6^{3+}$	Pale Yellow
hexaaquomanganese(II)	$Mn(H_2O)_6^{2+}$	Very Pale Pink
hexaaquocopper(II)	$Cu(H_2O)_6^{2+}$	Blue
hexaaquochromium(III)	$Cr(H_2O)_6^{3+}$	Green
hexaaquovanadium(II)	$V(H_2O)_6^{2+}$	Violet

Coloured Ions

- Transition metals form coloured compounds
- This is because they have lots of electron shells to choose from. As a ray of light hits a transition metal ion it causes the electrons to be bumped up to higher energy levels. Because it takes a specific amount of energy to move electrons to higher levels it sucks this energy level of light right out of the spectrum. A blue substance has absorbed every colour but blue
- If the primary colours that can make up white light are red, blue and green then what colour is reflected if only blue light is absorbed by a chemical?
- Zinc doesn't form coloured compounds because it's 3d sublevel is full

Examples of Ions and Their Colours

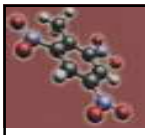
Name	Formula	Colour
Manganese (II)	Mn^{2+}	Very pale Pink
Manganese dioxide	MnO_2	Brown/Black
Permanganate	MnO_4^-	Purple
Chromium (III)	Cr^{3+}	Green (in solution)
Chromate	CrO_4^-	Yellow
Dichromate	$Cr_2O_7^{-2}$	Orange
Iron (II)	Fe^{2+}	Pale Green
Iron (III)	Fe^{3+}	Pale Yellow
Copper (II)	Cu^{2+}	Blue
Nickel (II)	Ni^{2+}	Green
Zinc (II)	Zn^{2+}	Colourless
Cobalt (II)	Co^{2+}	Red
Cobalt (III)	Co^{3+}	Blue



Oxidation States

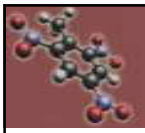
- An oxidation state is a fancy name for the charge of an ion. If it has lost one electron it has one extra positive charge (one more proton than its electrons). Therefore it's oxidation state is 1. If its gained three electrons it's oxidation state is -3

Ion	Oxidation State
Na^{+}	1
Al^{3+}	3
P^{3-}	-3



It's Not That Easy

- There's a catch, sometime they don't tell you what the charge is because its been hidden inside another chemical i.e. Al_2O_3. We may have to extract the oxidation state from a chemical by following a few rules:
  - Some ions always have the same charge – i.e. O = -2, H = +1
  - The total charge of the compound must equal the sum of its components
  - All elements have and oxidation state of zero



Examples – (It's as easy as algebra)

Cu_2O

1. Total = 0
2. There's 1x**O** = -2
3. So putting it together:

Cu_2 -2 = 0

Cu_2 = 2

Cu = 1

MnO_4^-

1. Total = -1
2. There's 4x**O** = -8
3. Putting it together:

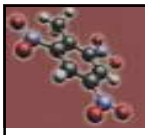
Mn – 8 = -1

Mn = 8-1

Mn = 7

Remember the rules:

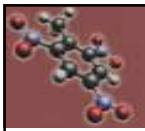
- Change the side change the sign (i.e. -2 became +2)
- What you do to one side you do to the other (i.e. We divided both sides by



Multiple Oxidation States

Note – see the Level 3 Electron Configuration notes before starting this section

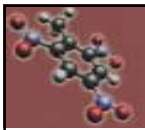
- Transition metals can have lots of different oxidation states i.e. Cu^+ and Cu^{2+}
- This is because they are filling up the 3d sublevel. They can choose to drop electrons from the 3d or the 4s or fill up half shells or bits and pieces of both (it gets messy). Here are the general rules:
  - The $4s^2$ electrons can be dropped, filled or half filled
  - The $3d^{10}$ electrons can be dropped, filled or half filled
  - Any combination of the above may be stable



Half Filled?

- It turns out that not only full sublevels are stable but also half filled shells are stable. This is because of electron spin.
- Electrons spin in certain directions. They fill up one directions spin first before moving on to the next spin direction. This means that in the 3d sublevel 5 electrons spin in each direction. Once one direction is filled the sublevel is stable

V (23 electrons)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$
V^{2+} (21 electrons)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$
V^{3+} (20 electrons)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
V^{4+} (19 electrons)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
V^{5+} (18 electrons)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$



Defining Acids and Bases

- Base – any chemical that absorbs H^+ (protons) is called an acid
  - Example: $H_2O + H^+ \longrightarrow H_3O^+$
- Acid – any chemical that can donate H+ (protons) is called a base
  - Example: $H_2O \longrightarrow OH^- + H^+$
- Amphoteric – any chemical that can act as an acid or a base
  - Example: Water (see the above examples)

Acidic, Amphoteric and Basic Oxides

- Transition metal form acidic oxides when they have high oxidation numbers such as 6 or 7
  - Examples: CrO_3 and Mn_2O_7
- Amphoteric oxides have an oxidation state of 3
  - Examples: Cr_2O_3 and Mn_2O_3
- Basic oxides have an oxidation state of 2
  - Examples: FeO, CrO, and MnO

Equations

- How could the following chemicals act like an acid, a base or both?
  - CrO_3
  - Mn_2O_3
  - FeO

Exam Practice - 2006

Have a go at Questions:

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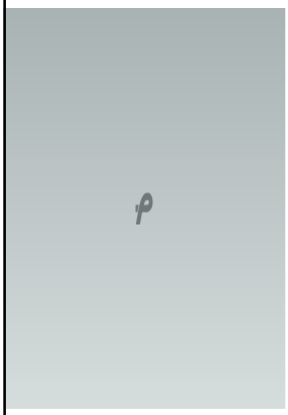

Exam Practice - 2007

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