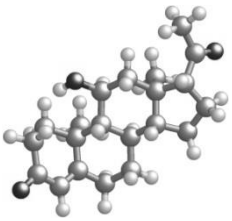

Chem!stry

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

Redox Reactions through Concept Development

1. Study each of the following chemical reactions:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

In these reactions, the carbon (C), carbon monoxide (CO) and sulfur dioxide (SO_2) have all been *oxidised*. Based upon this information, define the term *oxidised* / *oxidation*.

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2. Study each of the following chemical reactions:

$$2Ag_2O(s) \rightarrow 4Ag(s) + O_2(g)$$

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$$

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

In these reactions, the silver in the silver oxide (Ag_2O), the copper in the copper(II) oxide (CuO) and the iron in the iron(III) oxide (Fe_2O_3) have all been *reduced*. Based upon this information, define the term reduced / reduction.

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3. Study each of the following chemical reactions:

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

$$C_3H_8(g) \rightarrow C_3H_6(g) + H_2(g)$$

$$CH_3CH_2OH(l) \rightarrow CH_3COOH(l) + H_2(g)$$

In these reactions, the oxygen in the water (H_2O), the carbon in the propane (C_3H_8) and the carbon in the ethanol (CH_3CH_2OH) have all been *oxidised*. Based upon this information, define the term *oxidised* / *oxidation*.

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4. Study each of the following chemical reactions:

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

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$$

In these reactions, the nitrogen (N_2), oxygen (O_2) and ethene (C_2H_4) have all been *reduced*. Based upon this information, define the term *reduced* / *reduction*.

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5. Study each of the following chemical reactions:

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$$

$$2I^-(aq) \rightarrow I_2(aq) + 2e^-$$

$$CH_3CH_2OH(l) \rightarrow CH_3CHO(l) + 2H^+(aq) + 2e^-$$

In these reactions, magnesium (Mg), iodide ions (I^-) and the carbon in ethanol (CH_3CH_2OH) have all been *oxidised*. Based upon this information, define the term *oxidised* / *oxidation*.

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6. Study each of the following chemical reactions:

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

$$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

In these reactions, chlorine (Cl_2), iron(III) ions (Fe^{3+}) and the manganese in the manganate(VII) ion (MnO_4^-) have all been *reduced*. Based upon this information, define the term *reduced* / *reduction*.

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Note: Students often use the mnemonic OIL RIG to help them remember the relationship between oxidation / reduction and the loss / gain of electrons.

- O…… I…… L…… of electrons.

- R…… I…… G…… of electrons.

7. Change in oxidation state.

Part One – Inductive Reasoning

• The oxidation state (also referred to as the oxidation number) is an artificial construct invented by Chemists to help them understand redox better.

• The oxidation state is a number given to an **element**. This number is preceded by either a "+" sign or a "–" sign. In general, this number is the charge the atom of the element would have **if** it existed as an ion in the compound (even if the compound is a covalent compound).

Definition of Oxidation and Reduction:
An atom / element is **oxidised** when its oxidation state **increases**, and it is **reduced** when its oxidation state **decreases**.

• By examining the oxidation numbers of the different elements in the following substances or ions, derive the underlying rules that govern the assignment of oxidation numbers.

Substance or Ion	Element	Oxidation State of the Element
Magnesium metal, Mg	Magnesium	0
Chlorine gas, Cl_2	Chlorine	0
Graphite, C	Carbon	0
Iron(II) ion, Fe^{2+}	Iron	+2
Chloride ion, Cl^-	Chlorine	–1
Magnesium chloride, $MgCl_2$	Magnesium	+2
	Chlorine	–1
Lead(II) oxide, PbO	Lead	+2
	Oxygen	–2
Sodium carbonate, Na_2CO_3	Sodium	+1
	Carbon	+4
	Oxygen	–2
Nitric acid, HNO_3	Hydrogen	+1
	Nitrogen	+5
	Oxygen	–2
Manganate(VII) ion, MnO_4^-	Manganese	+7
	Oxygen	–2

Substance or Ion	Element	Oxidation State of the Element
Potassium sulfate, K_2SO_4	Potassium	+1
	Sulfur	+6
	Oxygen	–2
Carbon monoxide, CO	Carbon	+2
	Oxygen	–2
Ammonium ion, NH_4^+	Nitrogen	–3
	Hydrogen	+1
Aluminium hydroxide, $Al(OH)_3$	Aluminium	+3
	Oxygen	–2
	Hydrogen	+1
Hydrogen peroxide, H_2O_2	Hydrogen	+1
	Oxygen	–1
Sodium hydride, NaH	Sodium	+1
	Hydrogen	–1
Potassium dichromate(VI), $K_2Cr_2O_7$	Potassium	+1
	Chromium	+6
	Oxygen	–2

Assigning Oxidation Numbers

Rule 1: A pure element that is uncombined with other elements is assigned an oxidation state of .....

Rule 2: For simple ions, the oxidation state is simply the ..... on the ion.

Rule 3: In complex ions, the sum of the oxidation states ……...
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Rule 4: The oxidation state of hydrogen in all compounds is ....., except in metal hydrides where its oxidation state is .....

Rule 5: The oxidation state of oxygen in all compounds is ....., except in peroxides where its oxidation state is .....

Rule 6: The oxidation number of Group 1 elements (*e.g.* sodium) in their compounds is ....., for Group 2 elements (*e.g.* magnesium) in their compounds it is ....., and for aluminium in its compounds it is .....

Rule 7: There are many oxidation numbers for Group 17 elements in their compounds, but the most common one is .....

Rule 8: ……
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Part Two – Practice Questions

1) Write down the oxidation state of the named element in the following substances:

a) Manganese in Mn ..... **b)** Manganese in Mn^{2+} .....

c) Manganese in MnO_2 ..... **d)** Manganese in NH_4MnO_4 .....

e) Oxygen in H_2O_2 ..... **f)** Chromium in $CrCl_3$ .....

g) Chromium in $K_2Cr_2O_7$ ..... **h)** Sulfur in SO_3^{2-} .....

i) Sulfur in SO_2 ..... **j)** Sulfur in $(NH_4)_2SO_4$ .....

k) Nitrogen in NH_4^+ ..... **l)** Nitrogen in NO_3^- .....

m) Nitrogen in $Zn(NO_3)_2$ ..... **n)** Iron in Fe_2O_3 .....

o) Vanadium in V_2O_5 ..... **p)** Hydrogen in NaH .....

q) Carbon in CO_2 ..... **r)** Bromine in Br_2 .....

s) Chlorine in HOCl ..... **t)** Phosphorus in H_3PO_4 .....

u) Phosphorus in P_4 ..... **v)** Iron in $Fe(OH)_3$ .....

w) Chlorine in ClO_3^- ..... **x)** Chromium in CrO_3 .....

2) Name the following substances using oxidation states by filling in the brackets or writing down the name. Example:

MnO_2 Manganese(IV) oxide.

a) SO_2 Sulfur( ) oxide.

b) SO_3 Sulfur( ) oxide.

c) $CuSO_4$ Copper( ) sulphate.

d) $FeCl_3$ Iron( ) chloride.

e) $KMnO_4$ Potassium manganate( ).

f) N_2O Nitrogen( ) oxide.

g) $PbSO_3$ Lead( ) sulfate( ).

h) $FeSO_4$ Iron( ) sulfate( ).

3) Calculate the oxidation state of the element that is underlined at the start of the reaction and at the end of the reaction. Identify how the oxidation state of the element has changed during the reaction and hence state whether the element has been oxidised or reduced.

a) $\underline{Mn}O_2 + 4HCl \rightarrow \underline{Mn}Cl_2 + Cl_2 + 2H_2O$

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b) $2KI + \underline{Cl}_2 \rightarrow 2K\underline{Cl} + I_2$

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c) $4\underline{N}H_3 + 5O_2 \rightarrow 4\underline{N}O + 6H_2O$

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8. Oxidising agents and reducing agents.

- Notes on oxidising agents, *e.g.* acidified potassium manganate(VII):

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

→ Questions to consider:

a) Why is the potassium cation, K^+, not included in this ionic half-equation?

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b) What colour change would you observe during this reaction?

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c) What evidence is there that the acidified potassium manganate(VII) is an oxidising agent?

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d) Is the manganese (Mn) oxidised or reduced during this reaction? What is your evidence?

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e) Why must the potassium manganate(VII) be acidified?

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- Notes on reducing agents, *e.g.* iron(II) sulfate:

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

→ Questions to consider:

a) Why is the sulfate anion, SO_4^{2-}, not included in this ionic half-equation?

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b) What colour change would you observe during this reaction?

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c) What evidence is there that the iron(II) cation is a reducing agent?

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d) Is the iron(II) cation oxidised or reduced during this reaction? What is your evidence?

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- Using the information provided, write the overall ionic equation for the reaction between acidified potassium manganate(VII) and iron(II) sulfate:

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- Scan the QR code below for the answers to this assignment.

http://www.chemist.sg/redox/redox_worksheet_concept_ans.pdf