9.4 Transition elements

01. 0620_m20_qp_42 Q: 4

Iron is a typical transition element.

Iron:
- acts as a catalyst
- forms coloured compounds
- has more than one oxidation state.

(a) Name **one** major industrial process that uses iron as a catalyst and name the product made in this process.

process .....

product made .....
[2]

(b) When aqueous sodium hydroxide is added to aqueous iron(II) sulfate, a precipitate forms.

(i) What colour is this precipitate?

..... [1]

(ii) Write the ionic equation for this reaction. Include state symbols.

..... [3]

(c) Iron(II) sulfate can be converted to iron(III) sulfate by potassium manganate(VII) at room temperature.

(i) What is the role of potassium manganate(VII) in this reaction?

..... [1]

(ii) What condition must be used for this reaction to occur?

..... [1]

(iii) In terms of electron transfer, what happens to the iron(II) ions in this reaction?

..... [1]

(iv) State the colour change seen during this reaction.

from purple to ..... [1]

(d) Deduce the charge on the iron ion in each of these compounds.

FeF_3 .....

$Fe(NO_3)_3$ .....
[2]

[Total: 12]

02. 0620_p20_qp_40 Q: 4

Chromium is a transition element.

(a) (i) State **two** differences in the physical properties of chromium and sodium.

.....

..... [2]

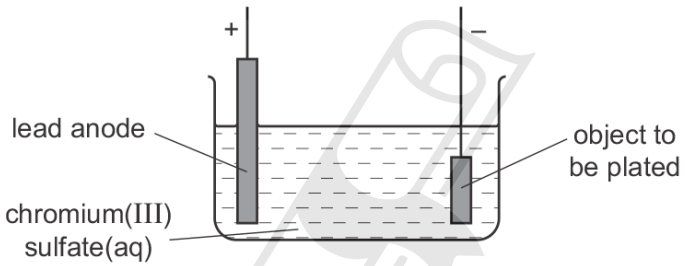
(ii) State **two** differences in the chemical properties of chromium and sodium.

.....

.....

..... [2]

(b) Chromium is used to electroplate steel objects. The diagram shows how this could be done.



(i) Give **two** reasons why steel objects are plated with chromium.

.....

..... [2]

(ii) The formula of the chromium(III) ion is Cr^{3+} and of the sulfate ion is SO_4^{2-}. Give the formula of chromium(III) sulfate.

..... [1]

(iii) Write the ionic half-equation for the reaction at the negative electrode (cathode).

..... [2]

(iv) A colourless gas, which relights a glowing splint, is formed at the positive electrode (anode).

State the name of this gas.

..... [1]

(v) During electroplating, it is necessary to add more chromium(III) sulfate but during copper plating using a copper anode, it is not necessary to add more copper(II) sulfate.

Explain this difference.

.....

.....

..... [2]

[Total: 12]

03. 0620_w20_qp_43 Q: 5

Group I elements, Group VII elements and transition elements are found in different parts of the Periodic Table.

(a) Describe the trend in the reactivity of Group I elements.

.....

..... [1]

(b) When potassium is added to water a chemical reaction occurs.

(i) State **two** observations that can be made when potassium is added to water.

.....

..... [2]

(ii) Write a chemical equation for the reaction of potassium with water.

..... [2]

(c) Excess aqueous potassium iodide is added to chlorine.

(i) Write a chemical equation for the reaction that occurs when aqueous potassium iodide is added to chlorine.

..... [2]

(ii) State the final colour of the reaction mixture.

..... [1]

(d) Sodium is extracted from sodium chloride by electrolysis.

(i) State the meaning of the term *electrolysis*.

.....

..... [2]

(ii) State what must be done to sodium chloride before it can be electrolysed to produce sodium.

..... [1]

(iii) Write an ionic half-equation for the change that occurs at the cathode during this electrolysis.

..... [1]

(e) Chromium is a transition element.

- Chromium has a high melting point.
- Chromium is a good conductor of electricity.
- Many chromium compounds are soluble in water.
- Hydrated chromium(III) sulfate is green.
- Chromium forms the chlorides $CrCl_2$ and $CrCl_3$.
- Oxides of chromium act as catalysts in the manufacture of poly(ethene).

(i) Use this information to give **two** properties of chromium which are different from properties of Group I elements such as sodium.

1 .....

2 .....

[2]

(ii) Use this information to give **two** properties of chromium which are similar to properties of Group I elements such as sodium.

1 .....

2 .....

[2]

[Total: 16]

04. 0620_s18_qp_41 Q: 5

(a) The table gives some chemical properties of transition elements and their compounds, and of Group I elements and their compounds.

chemical property	transition elements	Group I elements
ability to act as catalysts	yes	no
exist as coloured compounds	yes	no

(i) What is meant by the term *catalyst*?

.....

.....

..... [2]

(ii) Give **one** other chemical property shown by transition elements which is **not** shown by Group I elements.

..... [1]

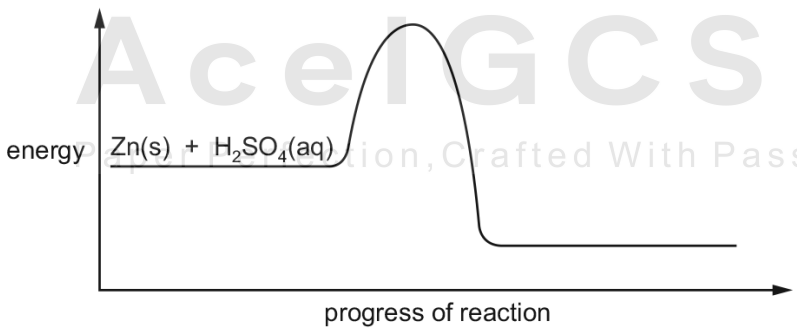
(b) Give **two** physical properties shown by transition elements which are **not** shown by Group I elements.

1 .....

2 .....

[2]

(c) The energy level diagram shows the energy profile for the reaction between zinc and dilute sulfuric acid.



(i) Complete the diagram by adding the formulae of the products. Include state symbols. [3]

(ii) Draw an arrow on the diagram to represent the activation energy. [1]

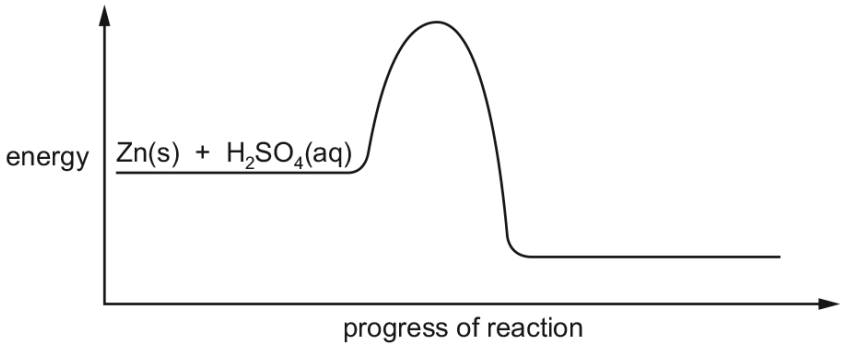
(iii) Is the reaction endothermic or exothermic? Explain your answer.

.....

..... [1]

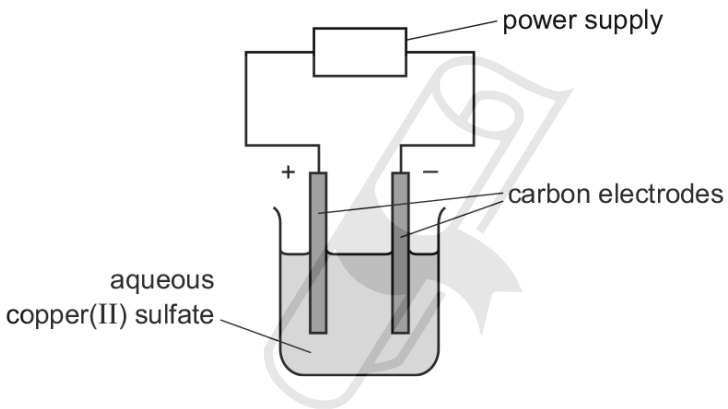
(d) The reaction between zinc and dilute sulfuric acid can be catalysed by the addition of aqueous copper(II) sulfate.

On the diagram, add the energy profile for the catalysed reaction.



[1]

(e) A student electrolyses aqueous copper(II) sulfate using the apparatus shown.



Oxygen gas forms at the positive electrode (anode).

(i) Write an ionic half-equation for the reaction at the negative electrode (cathode). Include state symbols.

..... [3]

(ii) Describe what the student observes at the negative electrode.

..... [1]

(iii) Give **two other** observations which the student makes during the electrolysis.

1 .....

2 .....

[2]

(iv) What difference would the student observe at the positive electrode if the aqueous copper(II) sulfate were replaced by concentrated aqueous copper(II) chloride?

..... [1]

[Total: 18]

05. 0620_m16_qp_42 Q: 4

Hydrogen peroxide, H_2O_2, decomposes into water and oxygen in the presence of a catalyst, manganese(IV) oxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

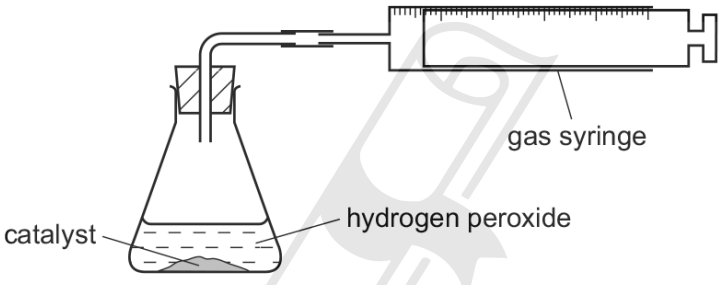
(a) What is meant by the term *catalyst*?

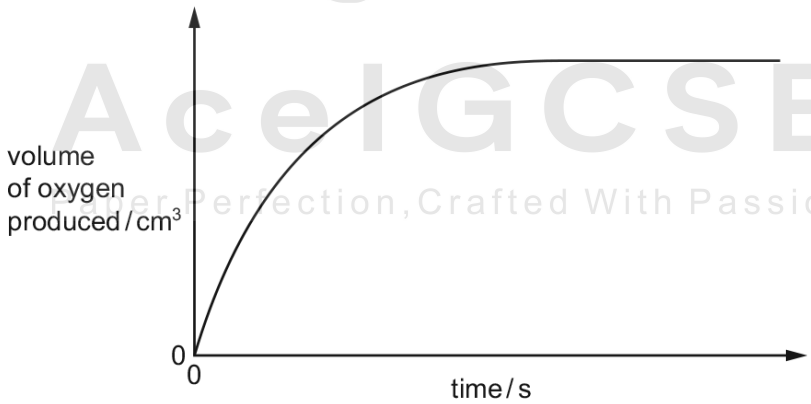
.....

..... [2]

(b) A student studies the rate of decomposition of hydrogen peroxide using the apparatus shown. The student uses 20 cm^3 of 0.1 mol / dm^3 hydrogen peroxide and 1.0 g of manganese(IV) oxide.

The student measures the volume of oxygen given off at regular time intervals until the reaction stops. A graph of the results is shown.





(i) When is the rate of reaction highest?

..... [1]

(ii) Suggest **one** method of increasing the rate of reaction using the same amounts of hydrogen peroxide and manganese(IV) oxide.

..... [1]

(c) (i) Calculate the number of moles of hydrogen peroxide used in this experiment.

..... mol [1]

(ii) Use your answer to **(c)(i)** and the equation to calculate the number of moles of oxygen produced in the reaction.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

..... mol [1]

(iii) Calculate the volume (at r.t.p.) of oxygen produced.

..... dm^3 [1]

(iv) What would be the effect on the volume of oxygen produced if the mass of catalyst was increased?

..... [1]

(v) Deduce the volume of oxygen that would be produced if 20 cm^3 of 0.2 mol / dm^3 hydrogen peroxide was used instead of 20 cm^3 of 0.1 mol / dm^3 hydrogen peroxide.

..... dm^3 [1]

(d) The student carries out a second experiment to investigate whether another substance, copper(II) oxide, is a better catalyst than manganese(IV) oxide.

Describe how the second experiment is carried out. You should state clearly how you would make sure that the catalyst is the only variable.

.....

.....

.....

.....

.....

..... [3]

[Total: 12]

06. 0620_p16_qp_40 Q: 4

Chromium is a transition element.

(a) (i) State **two** differences in the physical properties of chromium and sodium.

.....

..... [2]

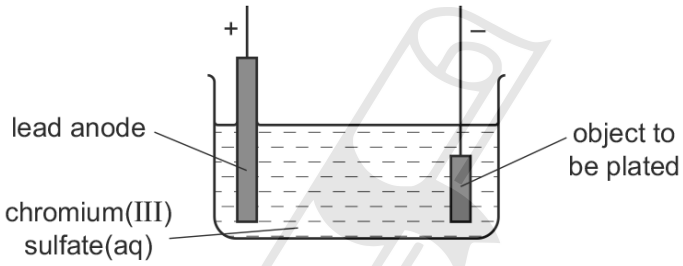
(ii) State **two** differences in the chemical properties of chromium and sodium.

.....

.....

..... [2]

(b) Chromium is used to electroplate steel objects. The diagram shows how this could be done.



(i) Give **two** reasons why steel objects are plated with chromium.

.....

..... [2]

(ii) The formula of the chromium(III) ion is Cr^{3+} and of the sulfate ion is SO_4^{2-}. Give the formula of chromium(III) sulfate.

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(iii) Write the ionic half-equation for the reaction at the negative electrode (cathode).

..... [2]

(iv) A colourless gas, which relights a glowing splint, is formed at the positive electrode (anode).

State the name of this gas.

..... [1]

(v) During electroplating, it is necessary to add more chromium(III) sulfate but during copper plating using a copper anode, it is not necessary to add more copper(II) sulfate.

Explain this difference.

.....

.....

..... [2]

[Total: 12]

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07. 0620_s14_qp_32 Q: 6

Scandium, proton number 21, is not a typical transition element.

(a) Scandium is a low density metal which has only one oxidation state in its compounds. Scandium compounds are white solids which form colourless solutions. Titanium, the next metal in the period, is a far more typical transition element. How would the properties of titanium differ from those of scandium?

.....

.....

.....

..... [3]

(b) Scandium fluoride is an ionic compound. The valency of scandium in scandium fluoride is three.
Draw a diagram which shows the formula of this compound, the charges on the ions and the arrangement of the valency electrons around the negative ions.

Use × to represent an electron from a fluorine atom.
Use o to represent an electron from a scandium atom.

[3]

(c) Scandium oxide is insoluble in water. Describe how you could show that it is an amphoteric oxide.

.....

.....

.....

..... [3]

[Total: 9]

08. 0620_w13_qp_32 Q: 5

Silver(I) chromate(VI) is an insoluble salt. It is prepared by precipitation.

20 cm^3 of aqueous silver(I) nitrate, concentration 0.2 mol/dm^3, was mixed with 20 cm^3 of aqueous potassium chromate(VI), concentration 0.1 mol/dm^3. After stirring, the mixture was filtered. The precipitate was washed several times with distilled water. The precipitate was then left in a warm oven for several hours.

$$2AgNO_3(aq) + K_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2KNO_3(aq)$$

(a) What difficulty arises if the name of a compound of a transition element does not include its oxidation state, for example iron oxide?

.....

..... [2]

(b) These questions refer to the preparation of the salt.

(i) Why is it necessary to filter the mixture after mixing and stirring?

..... [1]

(ii) What is the purpose of washing the precipitate?

..... [1]

(iii) Why leave the precipitate in a warm oven?

..... [1]

(c) **(i)** Explain why the concentrations of silver(I) nitrate and potassium chromate(VI) are different.

..... [1]

(ii) What mass of silver(I) nitrate is needed to prepare 100 cm^3 of silver(I) nitrate solution, concentration 0.2 mol/dm^3?
The mass of one mole of $AgNO_3$ is 170 g.

.....

..... [2]

(iii) What is the maximum mass of silver(I) chromate(VI) which could be obtained from 20 cm^3 of aqueous silver(I) nitrate, concentration 0.2 mol/dm^3?

number of moles of $AgNO_3$ used = ... [1]

number of moles of Ag_2CrO_4 formed = ... [1]

mass of one mole of Ag_2CrO_4 = 332 g

mass of Ag_2CrO_4 formed = ... g [1]

[Total: 11]

01. 0620_m20_ms_42 Q: 4

(a)	Haber (process) (1) ammonia (1)	**2**
(b)(i)	green	**1**
(b)(ii)	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ $Fe(OH)_2$ (as only product) (1) Fe^{2+} and $2OH^-$ (as reactants) (1) state symbols (1)	**3**
(c)(i)	oxidising agent	**1**
(c)(ii)	presence of an acid	**1**
(c)(iii)	lose an electron	**1**
(c)(iv)	colourless	**1**
(d)	3+ 3+	**2**

02. 0620_p20_ms_40 Q: 4

(a) (i) Any two from:
chromium
is harder;
has higher density;
has higher melting point / boiling point;
stronger;
ora; [2]
note: comparison must be made

(ii) Any two from:
sodium is more reactive;
chromium has more than one oxidation state, sodium has one;
chromium forms coloured compounds, sodium compounds are white;
sodium reacts with cold water, chromium does not;
chromium forms complex ions, sodium does not;
chromium has catalytic properties, sodium does not; [2]
note: difference must be clear

(b) (i) Any two from:
appearance / shiny / more attractive / decoration;
resists corrosion / resists rusting;
hard surface; [2]

(ii) $Cr_2(SO_4)_3$ [1]
ignore: correct charges on ions

(iii) $Cr^{3+} + 3e \rightarrow Cr$ [2]
note: one mark for equation and one mark for correct balancing

(iv) oxygen / O_2 [1]

(v) to replace chromium ions (used to plate steel) / chromium ions used up; [1]
copper ions replaced from copper anode; [1]

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03. 0620_w20_ms_43 Q: 5

Question	Answer	Marks
(a)	become more reactive down the group **ORA** (1)	1
(b)(i)	one mark each for **any two** of: • floats • dissolves / disappears / melts • moves • bubbles / fizzes / effervesces • lilac flame	2
(b)(ii)	$2K + 2H_2O \rightarrow 2KOH + H_2$ all formulae (1) equation fully correct (1)	2
(c)(i)	$Cl_2 + 2KI \rightarrow 2KCl + I_2$ **OR** $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$ all formulae (1) equation fully correct (1)	2
(c)(ii)	brown / black	1
(d)(i)	**breakdown** by (the passage of) **electricity** (1) of an **ionic compound** in **molten or aqueous** (state) (1)	2

Question	Answer	Marks
(d)(ii)	heat until it melts / heat to or above melting point	1
(d)(iii)	$Na^+ + e \rightarrow Na$	1
(e)(i)	one mark for each of any two from: • (chromium has) high melting point **ORA** • (chromium forms) coloured ions / coloured compounds **ORA** • (chromium has) variable valency / variable oxidation state / variable oxidation number **ORA** • catalytic behaviour **ORA** **ORA ALLOW** group 1 **or** sodium **if stated** • no colour **or** white **or** colourless ions or compounds • fixed valency / +1 charge **only or one** oxidation state / forms **one** chloride • low melting point • doesn't behave as a catalyst	2
(e)(ii)	one mark for each of any two from: • (chromium / sodium) **conducts** electricity • (chromium / sodium) compounds are **soluble** (in water) • (chromium / sodium) form hydrated salts / form hydrated compounds	2

04. 0620_s18_ms_41 Q: 5

(a)(i)	(a substance which) increases the rate of a reaction	1
	without being used up (at the end) / remains unchanged or unaffected or without changing mass	1
(a)(ii)	variable oxidation states	1
(b)	any **two** from: high(er) melting point / boiling point (very) hard(er) (very) strong(er) dense(r)	2
(c)(i)	$ZnSO_4$	1
	H_2 written on product line	1
	states (aq) **AND** (g)	1
(c)(ii)	(labelled) arrow pointing upwards starting level with reactants and finishing level with top of the hump.	1
(c)(iii)	exothermic **AND** products are at lower energy (than reactants)	1
(d)	lower hump starting from reactants line	1
(e)(i)	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ 1 mark for any equation which has Cu as the product or Cu^{2+} ions on left 1 mark for correct species 1 mark for correct state symbols	3
(e)(ii)	(a pink / brown) solid / deposit forms	1
(e)(iii)	bubbles / fizzing (at the anode)	1
	solution becomes paler / less blue / colourless	1

(e)(iv)	a green gas would be seen (on the anode)	1

05. 0620_m16_ms_42 Q: 4

(a)	**M1** (substance that) speeds up a reaction / increases the rate of a reaction; **M2** any one from: unchanged (chemically at the end) / not used up; lowers activation energy;	**2**
(b)(i)	at the start/initially / t = 0;	**1**
(b)(ii)	catalyst should be powdered / increase surface area (of catalyst) / decrease particle size (of catalyst); **or** increase temperature / heat / warm;	**1**
(c)(i)	0.002 (mol);	**1**
(c)(ii)	0.001 (mol);	**1**
(c)(iii)	0.024 (dm^3);	**1**
(c)(iv)	no change / no effect;	**1**
(c)(v)	0.048 (dm^3);	**1**
(d)	same mass / amount of / moles / 1.0 g of catalyst; same temperature; same volume **and** concentration of hydrogen peroxide / 20 cm^3 of 0.1 mol / dm^3 of hydrogen peroxide or reactant;	**3**

06. 0620_p16_ms_40 Q: 4

(a) (i) Any two from:
chromium
is harder;
has higher density;
has higher melting point / boiling point;
stronger;
ora; [2]
note: comparison must be made

(ii) Any two from:
sodium is more reactive;
chromium has more than one oxidation state, sodium has one;
chromium forms coloured compounds, sodium compounds are white;
sodium reacts with cold water, chromium does not;
chromium forms complex ions, sodium does not;
chromium has catalytic properties, sodium does not; [2]
note: difference must be clear

(b) (i) Any two from:
appearance / shiny / more attractive / decoration;
resists corrosion / resists rusting;
hard surface; [2]

(ii) $Cr_2(SO_4)_3$ [1]
ignore: correct charges on ions

(iii) $Cr^{3+} + 3e \rightarrow Cr$ [2]
note: one mark for equation and one mark for correct balancing

(iv) oxygen / O_2 [1]

(v) to replace chromium ions (used to plate steel) / chromium ions used up; [1]
copper ions replaced from copper anode; [1]

07. 0620_s14_ms_32 Q: 6

(a) any **three** from:
(it would have) more than one or variable valency / oxidation state / oxidation number (1)

(metal / element / titanium / it has a) high density (1)

coloured compounds / ions / solutions (1)

form complex (ions) (1)

(element/compound act as) catalyst (1) [3]

(b) ScF_3 (1)

correct charges on **both** ions (1)

8 electrons around (each) fluoride (1) [3]

(c) name or formula of strong acid and alkali (1)

reacts with or neutralises both acid and base or alkali (then amphoteric) (1)

it dissolves / soluble in both(acid and alkali) or form solutions in both (1) [3]

[Total: 9]

08. 0620_w13_ms_32 Q: 5

(a) because they have more than one oxidation state or valency / form ions with different charges [1]

there are two iron oxides (iron(III) oxide and iron(II) oxide) / iron forms Fe^{2+} and Fe^{3+} compounds / iron forms iron(II) and iron(III) compounds [1]

(b) (i) to remove the precipitate / remove the silver(I) chromate(VI) / remove the residue [1]

(ii) to remove soluble impurities / remove named soluble salt e.g. potassium nitrate / remove reactants [1]

(iii) to dry solid / to remove water [1]

(c) (i) need one mole of potassium chromate(VI) for two moles of silver(I) nitrate / correct references to mole ratio [1]

(ii) mass of $AgNO_3$ needed is 170 × 0.2 × 0.1 = 3.4g [2]
NOTE: if answer given is 34 they have omitted 0.1
ALLOW: (1) ecf

(iii) number of moles of $AgNO_3$ used = 0.02 × 0.2 = 0.004 [1]

number of moles of Ag_2CrO_4 formed = 0.002 [1]

mass of one mole of Ag_2CrO_4 = 332g

mass of Ag_2CrO_4 formed = 0.664g [1]
NOTE: use ecf when appropriate

[Total: 11]