Chemistry · Transition Elements

General Properties of the First Transition Series

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Multiple choice questions — 65 questions

1 As the atomic number of the transition elements in the same period increases .....

(A) the ionization energy decreases.
(B) the radius increases.
(C) the density decreases.
(D) oxidation becomes more difficult.

2 Two elements (X) , (Y) of the first transition series, each with its 4s sublevel half-filled with electrons, and element (X) comes before element (Y).

Which of the following is incorrect?

(A) The atomic radius of element (X) = the atomic radius of element (Y).
(B) The number of electrons in the (3d) sublevel of element (Y) is twice that of element (X).
(C) The oxidation states of the two elements (X , Y) do not exceed the group number of each of them.
(D) The two elements (X , Y) are more electronically stable in the atomic state.

3 Four transition elements of the first series (A , B , C , D) :

- (A) : smallest atomic radius.
- (B) : highest boiling point.
- (C) : highest density.
- (D) : highest melting point.

What is the correct order of the four elements according to the effective nuclear charge?

(A) D > B > A > C (B) C > A > D > B (C) A > D > B > C (D) B > C > A > D

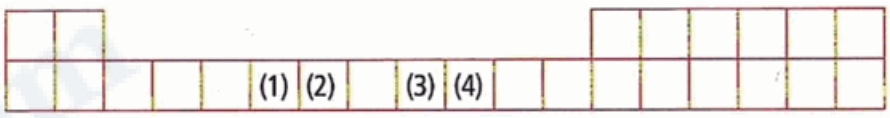
4 Two elements (X) , (Y) of the first transition series have the same number of unpaired electrons in the oxidation state $(+2)$.

If (X) can be magnetized, then .....

(A) the density of (Y) is greater than that of (X).
(B) the atomic mass of (Y) is greater than that of (X).
(C) the atomic radius of (X) is greater than that of (Y).
(D) the effective nuclear charge of element (X) is greater than that of (Y).

5 The following figure shows a part of the periodic table :

Each of the following is correct, except .....



(A) The atomic mass of element (4) is greater than that of element (3).

(B) The melting point of element (1) is greater than that of element (3).

(C) The atomic radii of elements (1) , (2) are equal.

(D) The density of element (2) is less than that of element (3).

---

6 The atoms of the transition element used in tanning leather have something in common with the atoms of the transition element added to aluminium to make the alloy used in making soft-drink cans, which is .....

(A) the number of unpaired electrons.

(B) the number of electrons in the (d) sublevel.

(C) the melting point.

(D) the number of oxidation states.

---

7 The opposite table shows the atomic radii of four successive elements of the first transition series.

Which of these elements has the highest density?

Atomic radius of the element (Å)	Element
1.16	(W)
1.16	(X)
1.15	(Y)
1.17	(Z)

(A) (W) (B) (X) (C) (Y) (D) (Z)

---

8 What is the similarity between scandium and zinc?

(A) Both are used in galvanizing steel.

(B) Each of them has only one oxidation state.

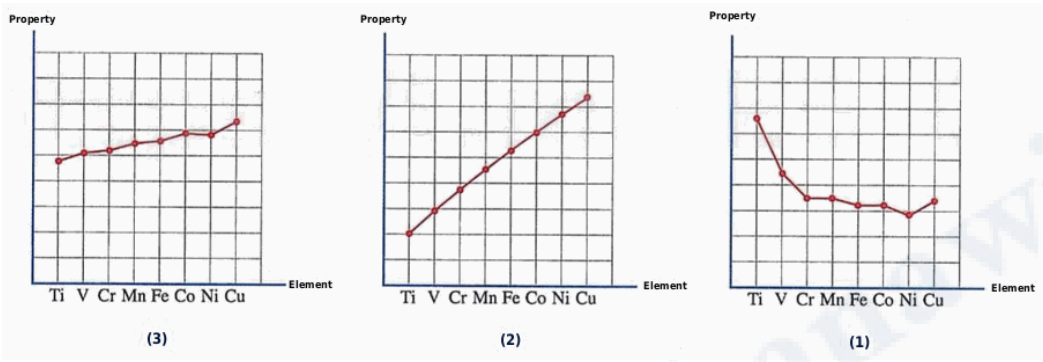
(C) Their densities are close.

(D) They have the same atomic size.

---

9 From the following graphs :

Which of the following shows the property shown by each of figures (1) , (2) , (3), respectively?



(A) (1) : atomic radius , (2) : effective nuclear charge , (3) : atomic mass.

(B) (1) : atomic mass , (2) : effective nuclear charge , (3) : atomic radius.

(C) (1) : atomic radius , (2) : atomic mass , (3) : effective nuclear charge.

(D) (1) : effective nuclear charge , (2) : atomic radius , (3) : atomic mass.

---

10 The metal (A) lies in the fourth period of the periodic table :

- it reacts with silicon forming the compound A_2Si
- it is used in making magnets.
- its atomic radius is the same as the atomic radius of the metal (B).

then the two metals (A) , (B) are .....

(A) (A) : Fe , (B) : Ni

(B) (A) : Cu , (B) : Ni

(C) (A) : Co , (B) : Cu

(D) (A) : Co , (B) : Fe

---

11 What is the correct order of the density of the following metals?

(A) Sc < V < Ni < Co (B) Sc < V < Co < Ni (C) Sc < Ni < Co < V (D) Co < Ni < V < Sc

---

12 From the following statements :

- Metal (1) : used as a catalyst in making ammonia gas.
- Metal (2) : one of its compounds is used in making Fehling's solution.
- Metal (3) : used in tanning leather.
- Metal (4) : used in making mercury vapour lamps.

The least chemically active of these metals is .....

(A) (1) (B) (2) (C) (3) (D) (4)

13 Which of the following describes the transition element (M), a solution of one of whose compounds is used to detect glucose?

(A) Very chemically active.

(B) Of limited chemical activity.

(C) Smaller in radius than the element before it in the period.

(D) Higher in melting point than the element before it in the period.

14 Which of the following shows the properties of a transition element?

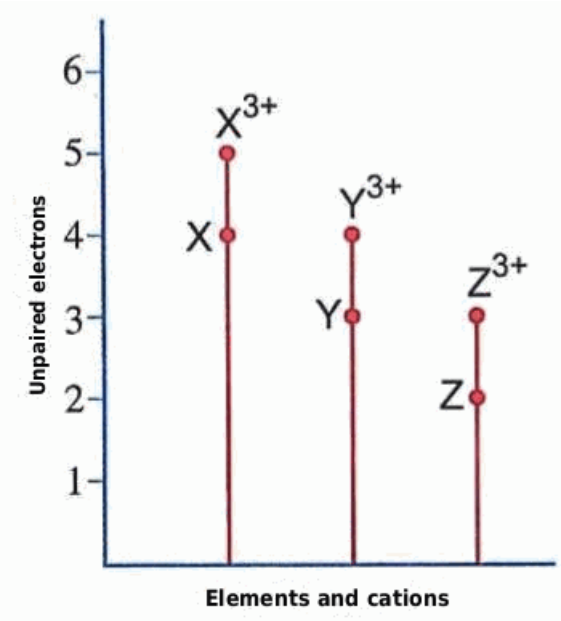
(A) Density : 0.97 g/cm^3 , melting point : 98°C

(B) Density : 2.64 g/cm^3 , melting point : 769°C

(C) Density : 3.1 g/cm^3 , melting point : −7°C

(D) Density : 8.96 g/cm^3 , melting point : 1085°C

15 The opposite graph is for some elements of the first transition series and their cations.
Which of the following is correct?



(A) The melting point of metal (X) is less than that of metal (Z).

(B) The atomic mass of metal (Y) is greater than that of metal (Z).

(C) The atomic mass of metal (X) is greater than that of metal (Y).

(D) Metal (Y) has more than one oxidation state, while metal (Z) has only one oxidation state.

---

16 Which of the following describes the properties of vanadium metal and of V_2O_5, respectively?

(A) Its density is greater than 5 g/cm³ / coloured.

(B) Its density is greater than 5 g/cm³ / colourless.

(C) Its density is less than 1 g/cm³ / coloured.

(D) Its density is less than 1 g/cm³ / colourless.

---

17 Which of the following shows the comparison between scandium and iron?

(A) Fourth ionization potential : scandium greater and iron less , reaction with water : scandium faster and iron slower

(B) Fourth ionization potential : scandium greater and iron less , reaction with water : scandium slower and iron faster

(C) Fourth ionization potential : scandium less and iron greater , reaction with water : scandium faster and iron slower

(D) Fourth ionization potential : scandium less and iron greater , reaction with water : scandium slower and iron faster

---

18 Three transition metals of the elements of the first transition series :

- Metal (X) : its density is the greatest compared with the other elements of the series.
- Metal (Y) : the number of its known oxidation states is 4.
- Metal (Z) : its melting point is the greatest compared with the other elements of the series.

These elements are arranged in increasing order of effective nuclear charge as follows .....

(A) (X) > (Z) > (Y) (B) (Z) > (X) > (Y) (C) (Y) > (X) > (Z) (D) (X) > (Y) > (Z)

---

19 Each of the following describes the properties of transition metals, except .....

(A) Their melting and boiling points are high.

(B) They have lustre and shine.

(C) They form ionic compounds.

(D) Most of them do not give the oxidation state +2

---

20 The compound $CuNO_3$ is .....

(A) paramagnetic and its cation is Cu^+ (B) paramagnetic and its cation is Cu^{2+}

(C) diamagnetic and its cation is Cu^+ (D) diamagnetic and its cation is Cu^{2+}

---

21 Which of the following pairs of compounds are paramagnetic?

(A) $ScCl_3$, $Zn(NO_3)_2$ (B) $ZnCl_2$, $CrCl_3$

(C) $Co(NO_3)_2$, $CrCl_3$ (D) $Co(NO_3)_2$, $ScCl_3$

---

22 Which of the following ions is a diamagnetic ion?

(A) Ti^{4+} (B) Mn^{2+} (C) Fe^{2+} (D) V^{2+}

23 The following compounds are repelled by an external magnetic field, except .....

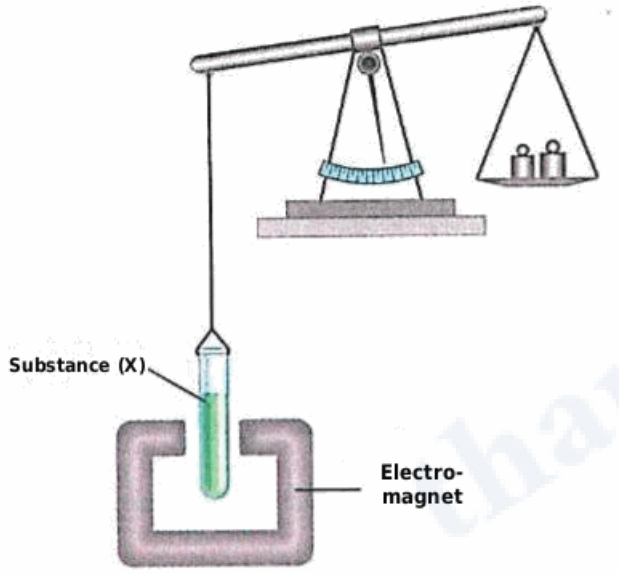
(A) $Sc_2(SO_4)_3$ (B) CuF_2 (C) $ZnSO_4$ (D) CuCl

24 Which of the following metals and its ion are repelled by an external magnetic field?

(A) Chromium. (B) Manganese. (C) Cadmium. (D) Iron.

25 From the opposite figure :

The cation of substance (X) may be .....



(A) $Ni^{2+}(aq)$, $Zn^{2+}(aq)$ (B) $Cu^{+}(aq)$, $Cr^{3+}(aq)$

(C) $Ni^{2+}(aq)$, $Cr^{3+}(aq)$ (D) $Cu^{+}(aq)$, $V^{3+}(aq)$

26 Each of the following shows the trend of the properties of some transition elements and their ions, except .....

(A) Number of unpaired electrons : $Fe^{3+} > Mn^{3+} > Sc^{3+}$

(B) Magnetic moment : $Mn^{2+} < Ni^{2+} < Co^{2+} < Fe^{2+}$

(C) Chemical activity : Sc > Fe > Cu

(D) Number of possible oxidation states : Sc < Ti < V < Mn

27 The solutions of which of the following substances increase in apparent weight when placed in an external magnetic field?

(A) TiO_2 (B) $Fe_2(SO_4)_3$ (C) $KMnO_4$ (D) $ScCl_3$

28 • Statement (1) : Zn^{2+} is a diamagnetic substance.

• Statement (2) : Zn loses two electrons from the 3d sublevel forming the ion Zn^{2+}

Which of the following describes each of the two statements (1) , (2)?

(A) Statement (1) is correct and statement (2) is wrong.

(B) Statement (1) is wrong and statement (2) is correct.

(C) Statement (1) is correct and statement (2) is correct.

(D) Statement (1) is wrong and statement (2) is wrong.

---

29 Which of the following shows the trend of the magnetic moment of the following ions?

(A) $V^{4+} < Ni^{2+} < Mn^{4+} < Fe^{3+}$

(B) $Mn^{4+} < V^{4+} < Ni^{2+} < Fe^{3+}$

(C) $V^{4+} < Ni^{2+} < Fe^{3+} < Mn^{4+}$

(D) $Fe^{3+} < Mn^{4+} < Ni^{2+} < V^{4+}$

---

30 Which of the following shows the trend of the paramagnetic property of the following ions?

(A) $Ti^{2+} > Mn^{2+} > Cr^{2+} > V^{2+}$

(B) $Mn^{2+} > Cr^{2+} > V^{2+} > Ti^{2+}$

(C) $V^{2+} > Ti^{2+} > Mn^{2+} > Cr^{2+}$

(D) $Mn^{2+} > Cr^{2+} > Ti^{2+} > V^{2+}$

---

31 The opposite table shows the group numbers of three metals of the first transition series :

(X) : group (IIB) , (Y) : group (IVB) , (Z) : group (IB)

What is the correct order of the ions of these metals according to their magnetic moment?

(A) $X^{2+} < Y^{2+} < Z^{2+}$ (B) $Z^{2+} < X^{2+} < Y^{2+}$ (C) $Y^{2+} < X^{2+} < Z^{2+}$ (D) $X^{2+} < Z^{2+} < Y^{2+}$

---

32 The metal (X) comes directly before the metal (Y) in the first transition series, both have the same atomic radius, and one salt of each of them is used as an oxidizing agent.

Which of the following describes the two oxides X_2O_3 , Y_2O_3 ?

(A) X_2O_3 is paramagnetic , Y_2O_3 is diamagnetic.

(B) The magnetic moment of the compound X_2O_3 is greater than that of the compound Y_2O_3

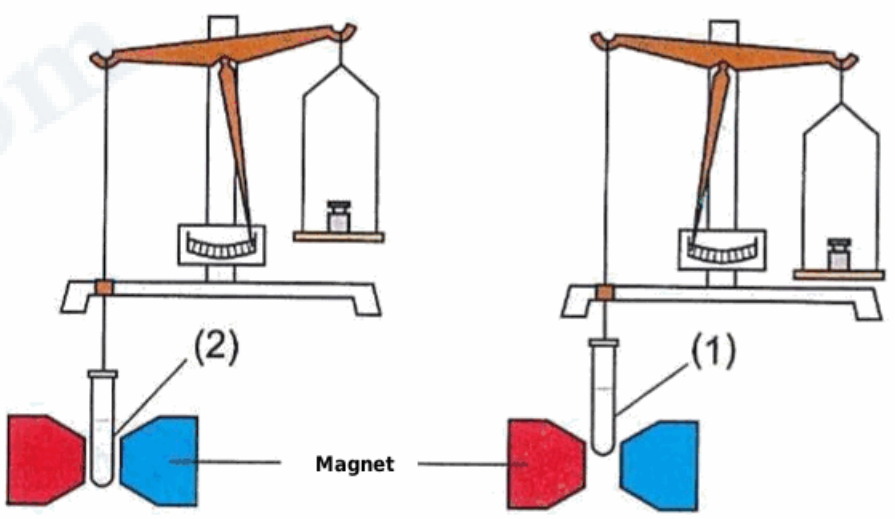
(C) The apparent weight of each of X_2O_3 , Y_2O_3 increases when placed in a magnetic field.

(D) The apparent weight of X_2O_3 decreases and the apparent weight of Y_2O_3 increases when placed in an external magnetic field.

---

33 From the two opposite figures :

Which of the following shows the cations of each of the two substances (1) , (2)?



(A) (1) : Fe^{2+} , (2) : Zn^{2+}

(B) (1) : Fe^{2+} , (2) : Cu^{+}

(C) (1) : Zn^{2+} , (2) : Cu^{+}

(D) (1) : Zn^{2+} , (2) : Fe^{2+}

34 Each of the following describes transition elements, except .....

(A) that all their ions are paramagnetic.

(B) that they are good conductors of heat and electricity.

(C) that the (d) sublevel is filled successively in them.

(D) that they lie between the (s) and (p) blocks.

35 All the following ions are diamagnetic, except .....

(A) $_{27}Co^{2+}$ (B) $_{30}Zn^{2+}$ (C) $_{47}Ag^{+}$ (D) $_{48}Cd^{2+}$

36 The magnetic moment of a transition metal is as large as possible when its d sublevel contains .....

(A) 2 electrons. (B) 5 electrons. (C) 7 electrons. (D) 9 electrons.

37 The magnetic moment μ of the atoms of elements and their ions is measured in BM and is found from the relation : $\mu = \sqrt{(n(n+2))}$, where n is the number of unpaired electrons.

Which of the following ions has a magnetic moment of 5.9 BM ?

(A) Fe^{2+} (B) Fe^{3+} (C) Ni^{2+} (D) Cu^{2+}

38 A transition element (A) of the first series whose highest oxidation state is less than its group number, and whose magnetic moment in its highest oxidation state is twice its magnetic moment in the atomic state.

Which of the following choices is correct?

(A) The radius of (A) is greater than that of the element after it in the same series.

(B) Element (A) has five stable isotopes.

(C) The melting point of (A) is higher than the melting point of the metal of electricity pylons.

(D) The density of element (A) is less than the density of the element that resists weather conditions.

---

39 How many elements ending with the electron configuration (4s , 3d) can form diamagnetic compounds in their highest oxidation states?

(A) 3 (B) 4 (C) 5 (D) 6

---

40 Which compound has a cation with the same magnetic moment as the cation of the compound that stops ultraviolet rays from reaching the skin?

(A) Cr_2O_3 (B) MnO_2 (C) V_2O_5 (D) CuO

---

41 A transition element of the first transition series reacts very vigorously with water.

Which of the following does not describe this element?

(A) Diamagnetic in the oxidation state $(+3)$.

(B) It has the highest boiling point compared with the elements of the first transition series.

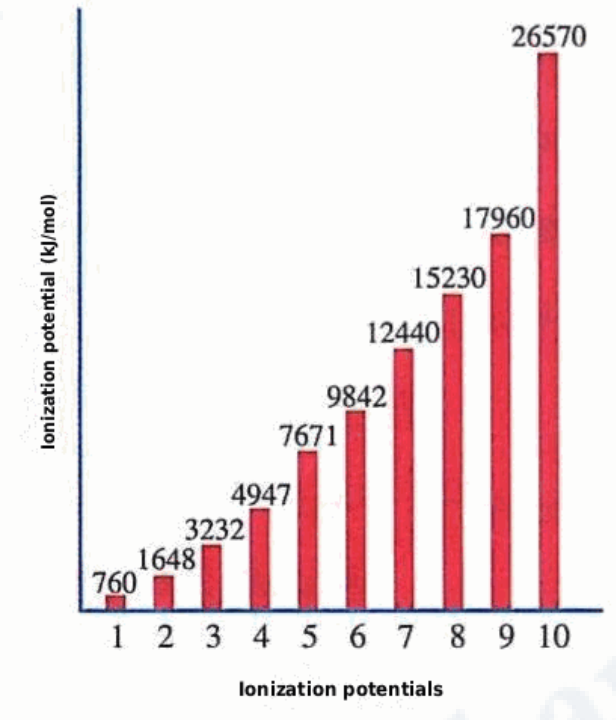
(C) Its electron configuration is ns^2 , $(n-1)d^{n-3}$

(D) It has many oxidation states.

---

42 The opposite graph shows the ionization potentials of a main transition element of the first series.

Each of the following describes this element, except .....



(A) It is used in making magnets.

(B) It has several radioactive isotopes.

(C) It lies in group 9

(D) It has paramagnetic compounds and diamagnetic compounds

---

43 The oxides of transition metals have many economic uses.

Which of the following describes an oxide of one of the metals?

(A) One use of the oxide : used in cosmetics , oxidation number of the metal in this oxide : +5

(B) One use of the oxide : used in making the dry cell , oxidation number of the metal in this oxide : +3

(C) One use of the oxide : a catalyst in the decomposition of H_2O_2 , oxidation number of the metal in this oxide : +4

(D) One use of the oxide : used in the rubber industry , oxidation number of the metal in this oxide : +4

---

44 Each of the following describes transition metals or their compounds used as catalysts in some industries, except .....

(A) V_2O_5 in making sulphuric acid.
(B) Fe in making ammonia.
(C) MnO_2 in making the dry cell.
(D) Ni in the hydrogenation of oils.

45 Among the properties of element (X) :

- its atomic mass is greater than that of the element before it.
- it gives compounds in which its oxidation number is +2 or +3
- it is used to lower the activation energy of some chemical reactions.

The group number of element (X) is .....

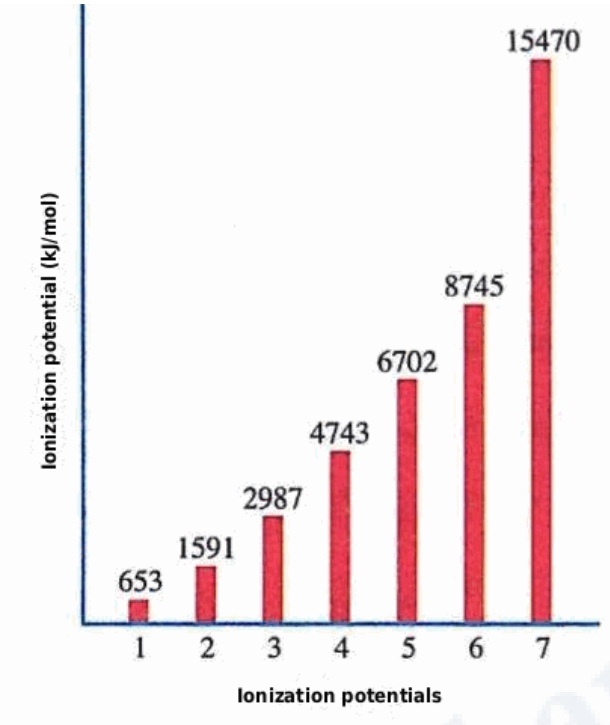
(A) 7 (B) 10 (C) 6 (D) 8

46 The electron configuration of the vanadium ion in the catalyst used in the contact process is the same as its electron configuration in the compound .....

(A) VO_2 (B) VN (C) VI_3 (D) NH_4VO_3

47 The opposite graph shows the ionization potentials of one of the elements of the first transition series.

Which of the following describes this element?



(A) Its use as a catalyst in making sulphuric acid.

(B) Its electron configuration is irregular.

(C) It can be magnetized.

(D) Its radius is equal to the radius of iron.

---

48 The catalysed reaction : $2SO_2 + O_2 \rightarrow (cat\ ,\ \Delta)\ 2SO_3$ is one of the steps in preparing a well-known compound.

What is the name of this method, and what is the electron configuration of the atom of the metal used in the catalyst in this process?

(A) Contact / [Ar] , $3d^0$, $4s^0$

(B) Fischer–Tropsch / [Ar] , $3d^5$, $4s^1$

(C) Fischer–Tropsch / [Ar] , $3d^3$, $4s^2$

(D) Contact / [Ar] , $3d^3$, $4s^2$

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49 Each of the following describes properties of most elements of the first transition series and their reasons, except .....

(A) Property : paramagnetic substances , reason : the presence of unpaired electrons in the 3d sublevel

(B) Property : their density is high , reason : their atomic sizes are close and their atomic masses are large

(C) Property : ideal catalysts , reason : the ease of losing the two 4s electrons

(D) Property : their melting point is high , reason : the strength of their metallic bonds

---

50 The opposite table shows some properties of one of the elements :

- Its melting point : 3422°C
- Its oxidation states : many.
- Density of the element : 19.52 g/cm^3
- Its electrical conductivity in the solid state : good.

What other property is this element expected to have?

(A) It has catalytic activity.

(B) The bonding forces between its atoms are weak.

(C) All its ions are diamagnetic.

(D) It lies in the fourth period and group 12

---

51 A transition element in the first series has a number of electrons in the (M) level twice its traditional group number in the periodic table.

Each of the following describes this element, except .....

(A) It lowers the activation energy of the hydrogenation of oils.

(B) It is used to make an alloy that resists corrosion while heated to redness.

(C) It has five stable isotopes.

(D) Its boiling point is higher than the boiling point of iron.

---

52 The metal (M) lies in the first transition series :

- its atomic mass is less than the atomic mass of cobalt.
- its melting point is higher than the melting point of nickel.
- its most stable compound with fluorine has the chemical formula : MF_5

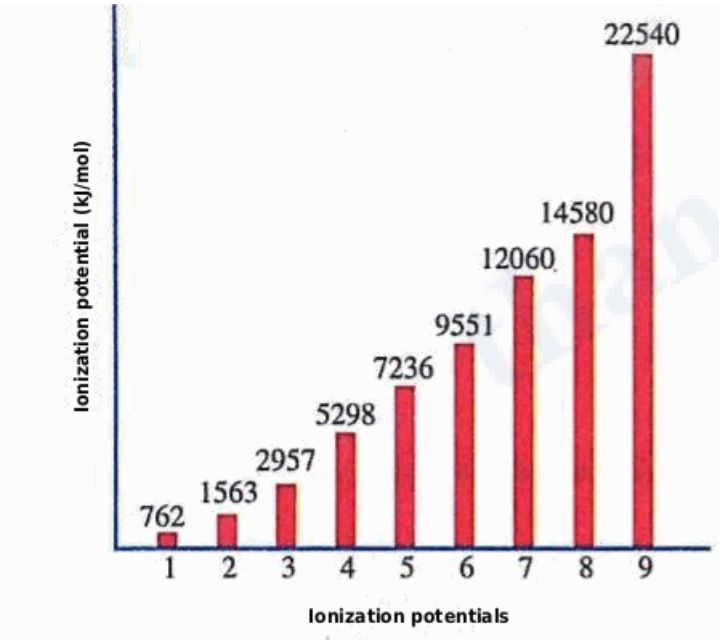
Its oxide is used as a catalyst in making .....

(A) ammonia by the Haber–Bosch process.
(B) hydrogenated oils.
(C) the dry cell.
(D) superconducting magnets.

---

53 The opposite graph shows the ionization potentials of a metallic element of the first transition series.

What is a characteristic of this element?



(A) It has only one oxidation state.
(B) Its 3d sublevel contains 3 unpaired electrons.
(C) It is used as an oxidizing agent in the Fischer–Tropsch process.
(D) It is used as a catalyst in making ammonia.

---

54 Two elements (A , B) of the first transition series contain the largest number of unpaired electrons, and element (B) gives more oxidation states than element (A).

Which of the following is correct?

(A) Element (B) comes before element (A).

(B) The compound $K_2A_2O_7$ is an oxidizing substance , BO_2 is a catalyst in the decomposition of H_2O_2

(C) Element (A) lies in group (VIIB) and element (B) lies in group (VIII).

(D) Element (A) resists weather conditions and element (B) is used in its pure state.

---

55 Three main transition elements (A , B , C) of the first series :

- (A) has the highest oxidation state in the first transition series.
- (B) has an oxidation state that exceeds its group number.
- (C) one of its compounds is used as a catalyst in preparing H_2SO_4 by the contact process.

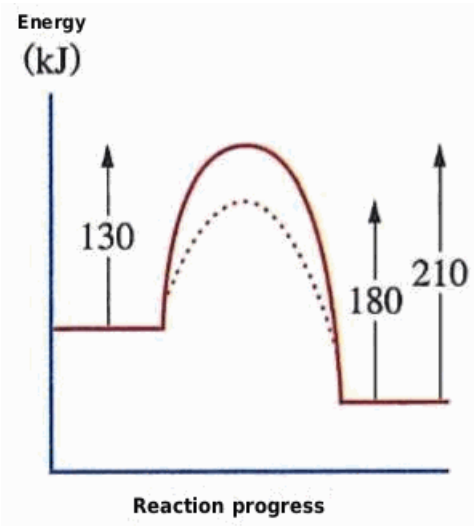
What is the correct order of the elements (A , B , C) according to boiling point?

(A) A > C > B (B) C > B > A (C) C > A > B (D) B > A > C

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56 The opposite figure shows the activation energy of a reaction before and after using a catalyst.

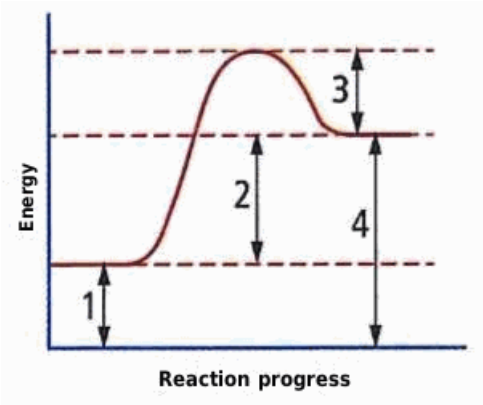
The activation energy of the catalysed reaction is .....



(A) 50 kJ (B) 100 kJ (C) 130 kJ (D) 180 kJ

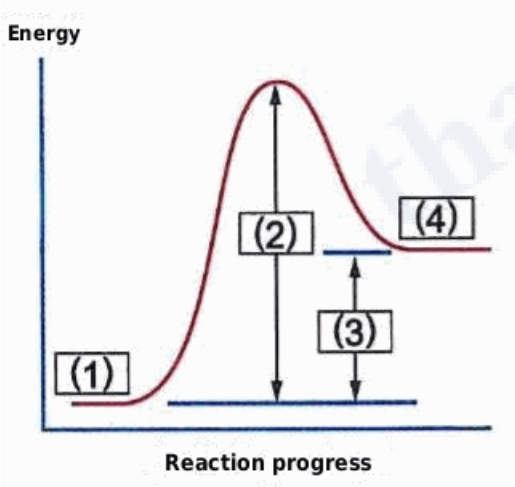
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57 The opposite figure shows the energy diagram of a chemical reaction,
Its activation energy is represented by the value .....



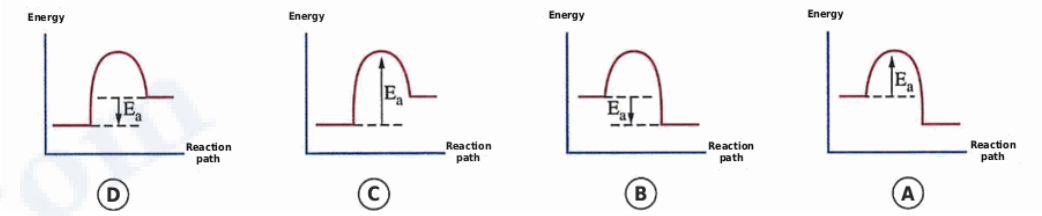
(A) 2 (B) 3 + 2 (C) 3 (D) 1 – 4

58 From the opposite energy diagram :
Which of the following is correct?



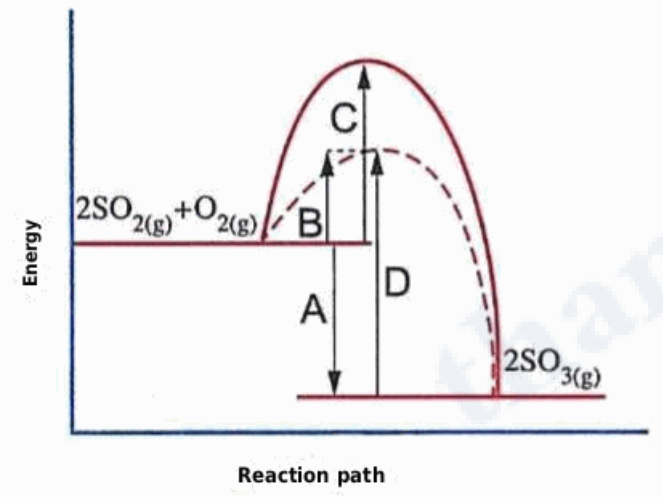
(A) (1) : energy of the reactants , (3) : activation energy.
(B) (1) : energy of the products , (2) : ΔH°
(C) (1) : energy of the reactants , (3) : ΔH°
(D) (2) : activation energy , (4) : energy of the reactants.

59 Which of the following graphs shows an exothermic reaction whose activation energy is E_a ?



(A) Figure (A) (B) Figure (B) (C) Figure (C) (D) Figure (D)

60 The following reaction : $2SO_2(g) + O_2(g) \longrightarrow (V_2O_5 , 450°C)\ 2SO_3(g)$, $\Delta H = -196$ kJ/mol is shown by the opposite energy diagram, in which the activation energy of the uncatalysed reaction is shown by the letter .....



61 The compound ammonium sulphate is produced by the reaction of ammonia and sulphuric acid.

Which of the following is correct?

(A) Compound : ammonia , method of preparation : contact , catalyst : iron

(B) Compound : ammonia , method of preparation : Haber – Bosch , catalyst : vanadium pentoxide

(C) Compound : sulphuric acid , method of preparation : contact , catalyst : vanadium pentoxide

(D) Compound : sulphuric acid , method of preparation : Haber – Bosch , catalyst : iron

62 Which of the following represents the properties of the metal most suitable for making car bodies?

(A) Density : high , strength and toughness : high , corrosion resistance : low

(B) Density : high , strength and toughness : low , corrosion resistance : low

(C) Density : low , strength and toughness : high , corrosion resistance : high

(D) Density : low , strength and toughness : low , corrosion resistance : high

---

63 In which of the following compounds does vanadium have the highest oxidation state?

(A) VCl_3 (B) $VOSO_4$ (C) Na_3VO_4 (D) VSO_4

---

64 A transition element (M) lies in the fourth period of the periodic table, and its atom contains three orbitals paired with electrons in the 3d sublevel; the electron configuration of the ion M^{4+} is the same as the electron configuration of the ion .....

(A) Cr^{3+} (B) Mn^{2+} (C) Fe^{2+} (D) Co^{4+}

---

65 Which of the following describes the properties of most transition elements?

(A) Melting point : high , their ions : diamagnetic , most of them used as catalysts : yes

(B) Melting point : high , their ions : paramagnetic , most of them used as catalysts : yes

(C) Melting point : low , their ions : diamagnetic , most of them used as catalysts : no

(D) Melting point : low , their ions : paramagnetic , most of them used as catalysts : no

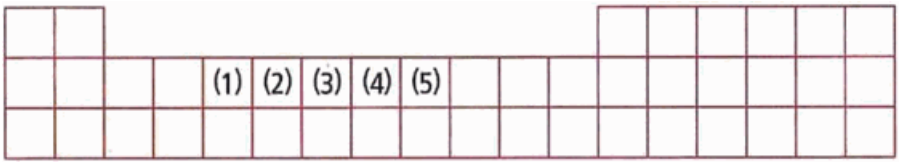
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Essay questions — 12 questions

1 The following figure shows a part of the periodic table :

(1) Give the numbers of the two elements that can be magnetized.

(2) Give two other similarities in physical properties between these two elements.



2 Two ions of metals of the first transition series have the electron configuration [Ar] , $3d^4$:

(1) Give the symbols of these two ions.

(2) Compare the effective nuclear charge of these two metals, and explain.

3 The transition metal (M) is added to steel to make the alloy used in making car springs.

Compare :

(1) the metal (M) and cobalt «in terms of : atomic mass».

(2) the metal (M) and nickel «in terms of : melting point».

4 Three metals (X) , (Y) , (Z) of the elements of the first transition series :

• Metal (X) : its density is greater than that of the other elements of the series.

• Metal (Y) : its stable oxidation number equals +5

• Metal (Z) : its melting point is higher than the melting points of the other elements of the series.

(1) Arrange these metals according to their boiling points.

(2) Which of the two metals (X) , (Y) has a relatively larger atomic radius?

5 From the following table, identify the non-transition element, supporting your choice with two reasons :

Element (G) : melting point 1083°C , density 8.92 g/cm³ , reaction with water : does not react , formulas of its chlorides : GCl , GCl_2

Element (J) : melting point 181°C , density 0.53 g/cm³ , reaction with water : very fast , formulas of its chlorides : JCl

Element (L) : melting point 1535°C , density 7.86 g/cm³ , reaction with water : very slow , formulas of its chlorides : LCl_2 , LCl_3

6 The metal (M) dissolves slowly in dilute sulphuric acid forming a solution of a paramagnetic compound, with gas bubbles given off.

Is the metal (M) scandium or iron? Support your choice with a scientific explanation.

7 Chromium metal dissolves quickly in dilute sulphuric acid forming a chromium (III) solution.

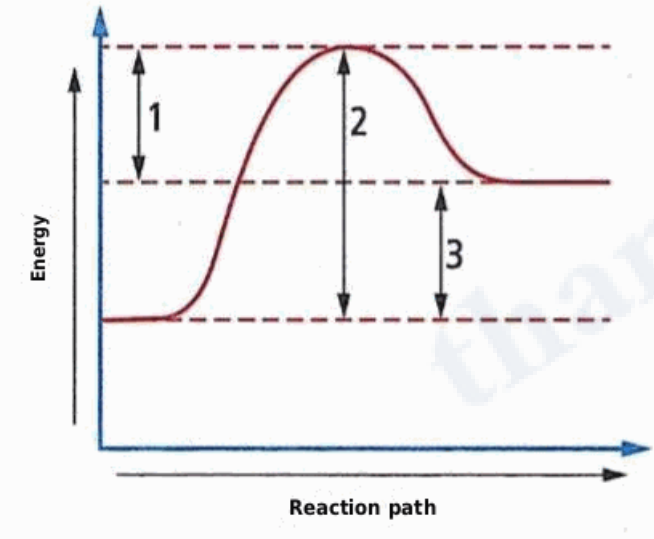
Write the balanced symbolic equation for this reaction.

8 The opposite figure shows the energy diagram of a chemical reaction,

What does each of the following represent :

(1) the difference between the two energy values (2) , (1).

(2) the sum of the two energy values (1) , (3).



9 Hydrogen peroxide H_2O_2 takes part in the following two reactions :

• Reaction (1) : when it is added to a $KMnO_4$ solution acidified with sulphuric acid, the colour of the permanganate disappears.

• Reaction (2) : when it is added to a $FeSO_4$ solution, the number of unpaired electrons of the cation of the salt increases.

What role does H_2O_2 play in the two previous reactions? Explain.

10 A transition metal (M) whose ion M^{3+} has the electron configuration [Ar] , $3d^5$:

(1) Can the metal (M) be magnetized?

(2) Is the radius of the metal (M) equal to that of the metal after it in the period or not?

11 The two metals (A) , (B) are elements of the first transition series and have the same atomic radius :

• Metal (A) : has the oxidation state +4 and the cation A^{4+} has 5 unpaired electrons.

• Metal (B) : has the oxidation state +2 and the cation B^{2+} has 4 unpaired electrons.

(1) State one use the two metals have in common.

(2) Which has the higher density, metal (A) or metal (B)?

---

12 From the transition metals (vanadium , chromium , manganese , titanium) :

(1) Arrange the doubly charged ions of these metals in increasing order of their magnetic moment.

(2) Arrange these elements in increasing order of effective nuclear charge.

Past exam questions — 32 questions

1 Two successive elements (X) , (Y) of the first transition series; element (X) has the highest oxidation state in the series.
Which of the following is correct?
(Sample exam 2026)

(A) Element (Y) is diamagnetic and its atom has 6 unpaired electrons.

(B) Element (X) is diamagnetic and its atom has 6 unpaired electrons.

(C) The ion Y^{2+} is paramagnetic and has 4 unpaired electrons.

(D) The ion X^{3+} is paramagnetic and has 5 unpaired electrons.

---

2 Two successive transition elements (X) , (Y) of the first transition series have the same number of electrons in the 3d sublevel
Which of the following is correct?
(Sample exam 2026)

(A) The effective nuclear charge of element (X) is greater than the effective nuclear charge of element (Y).

(B) The radius of element (X) is smaller than the radius of element (Y).

(C) The radius of element (X) equals the radius of element (Y).

(D) The repulsion between the 3d electrons of element (X) is less than the repulsion between the 3d electrons of element (Y).

---

3 Which of the following represents the correct order of the ions of some elements according to the strength of their attraction to a magnet?
(Sample exam 2026)

(A) $Fe^{2+} > Ti^{4+} > Mn^{2+}$

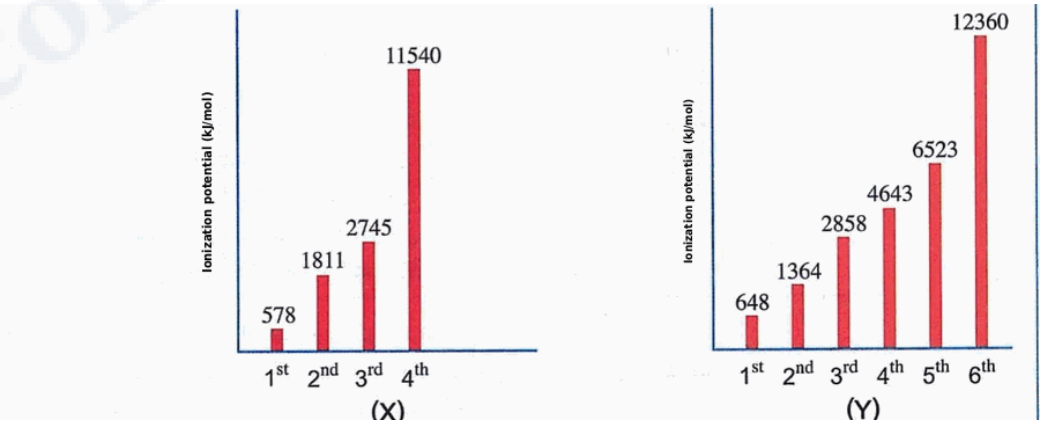
(B) $Mn^{2+} > Fe^{2+} > Ti^{4+}$

(C) $Mn^{2+} > Ti^{4+} > Fe^{2+}$

(D) $Ti^{4+} > Mn^{2+} > Fe^{2+}$

---

4 The following graphs show the values of the ionization potentials of two elements (X) , (Y) :
Which of the following shows the type of the two elements (X) , (Y) and the use of one alloy of each of them?
(Sample exam 2026)



(A) (X) transition : used in aircraft bodies
(B) (X) non-transition : used in MiG aircraft
(C) (Y) transition : used in railway rails
(D) (Y) non-transition : used in soft-drink cans

---

5 A transition element (X) of the first transition series is similar in its properties to the element before it and the element after it in the same group,
Which of the following changes happens easily for its ions?
(Sample exam 2026)

(A) $X^{3+} \longrightarrow X^{2+}$ (B) $X^{4+} \longrightarrow X^{3+}$ (C) $X^{3+} \longrightarrow X^{4+}$ (D) $X^{2+} \longrightarrow X^{3+}$

---

6 Two transition elements (X) , (Y) of the first transition series.
(X) : one of its oxides is used as a catalyst in making superconducting magnets.
(Y) : its atom contains twice the number of unpaired electrons found in element (X).
Which of the following is correct?
(Sample exam 2026)

(A) The atomic radius of element (Y) is less than that of the element after it in the series.
(B) The effective nuclear charge of element (Y) is less than that of element (X).
(C) The highest oxidation state of element (Y) is higher than that of element (X).
(D) The density of element (Y) is less than the density of the element before it in the series.

---

7 Two non-successive transition elements (X) , (Y) of the first transition series.
Element (X) : one of its compounds is used as a catalyst in the contact process.
Element (Y) : contains the same number of unpaired electrons as element (X).
Which of the following is correct?
(Sample exam 2026)

(A) The radius of element (X) is greater than the radius of the element directly before it in the series.

(B) The effective nuclear charge of element (Y) is less than that of element (X).

(C) The density of element (Y) is less than the density of element (X).

(D) The atomic mass of element (Y) is greater than the atomic mass of the element directly after it in the series.

---

8 Three successive elements (A) , (B) , (C) of the first transition series; element (A) has an electron configuration that is irregular compared with the other elements of the series.
Which of the following shows the correct order of the magnetic moment of the ions of these elements?
(Sample exam 2026)

(A) $A^{3+} > B^{3+} > C^{3+}$ (B) $B^{3+} > C^{3+} > A^{3+}$ (C) $B^{3+} > A^{3+} > C^{3+}$ (D) $C^{3+} > B^{3+} > A^{3+}$

---

9 Two successive transition elements (X) , (Y) of the first transition series contain the same number of electrons in the (3d) sublevel, and element (X) resists weather conditions.
Which of the following describes the properties of each of the two elements (X) , (Y)?
(Sample exam 2026)

(A) The density of element (Y) is less than the density of element (X).

(B) The atomic mass of element (X) is greater than the atomic mass of element (Y).

(C) The radius of element (X) is greater than the radius of element (Y).

(D) The effective nuclear charge of element (Y) is greater than that of element (X).

---

10 The elements (X) , (Y) , (Z) , (W) are transition elements of the first transition series.

(X) : after it, the pairing of electrons in the (3d) sublevel begins

(Y) : the first element in the series that does not lose all its (4s) , (3d) electrons

(Z) : its (d) sublevel is complete with electrons.

(W) : the highest magnetic moment in the series.

Which of the following changes produces a compound lower in energy?

(Sample exam 2026)

(A) $WO_3 \longrightarrow WO$ (B) $ZO \longrightarrow Z_2O_3$ (C) $Y_2O_3 \longrightarrow YO$ (D) $X_2O_3 \longrightarrow XO$

---

11 (A) , (B) , (C) are three elements of the first transition series :

The number of unpaired electrons in element (A) decreases when it changes from the atomic state to +2

The number of unpaired electrons in element (B) increases when it changes from +2 to +3

The number of unpaired electrons in element (C) decreases when it changes from +2 to +3 , and its radius equals that of (A)

Which of the following shows the correct trend of these elements according to their density?

(Sample exam 2026)

(A) A < B < C (B) A < C < B (C) B < C < A (D) B < A < C

---

12 (A) , (B) , (C) , (D) are four successive transition elements of the first transition series, and the electron configuration of the ion B^{3+} ends with $3d^3$

Which of the following is correct?

(Sample exam 2026)

(A) The magnetic moment of element (A) increases by losing two electrons.

(B) The magnetic moment of element (B) increases by losing two electrons.

(C) The magnetic moment of element (C) decreases by losing the first electron from the (d) level.

(D) The magnetic moment of element (D) decreases by losing the first electron from the (d) level.

---

13 An element (X) of the first transition series whose ion X^{2+} contains (11) orbitals filled with electrons and (3) half-filled orbitals.

Which of the following does not describe element (X)?

(Sample exam 2026)

(A) Its atomic mass is less than that of the element after it.

(B) Its density is less than that of the element after it.

(C) All its compounds are paramagnetic.

(D) Its effective nuclear charge is greater than that of the element before it.

---

14 (X) , (Y) , (Z) are three transition elements at the end of the first transition series, and their order according to atomic mass is (Y < Z < X)

Which of the following shows the correct order of the ions of these elements according to magnetic moment?

(Sample exam 2026)

(A) $Z^{2+} > Y^{2+} > X^{2+}$ (B) $X^{2+} > Y^{2+} > Z^{2+}$ (C) $Z^{2+} > X^{2+} > Y^{2+}$ (D) $X^{2+} > Z^{2+} > Y^{2+}$

---

15 A transition element (A) whose ion (A^{2+}) has a magnetic moment less than the magnetic moment of its atom.

Which of the following choices is correct for this element?

(1st session 2025)

(A) It is one of the coinage metals.

(B) It has the highest magnetic moment in its series.

(C) It has an oxidation state higher than its group number.

(D) All its compounds are paramagnetic.

---

16 The opposite part of the periodic table contains four elements A , B , C , D :
Which of the following choices is correct?
(1st session 2025)



(A) The effective nuclear charge of element (C) is less than the effective nuclear charge of element (B).

(B) The atomic mass of element (D) is less than the atomic mass of element (C).

(C) The density of element (A) is higher than the density of element (B).

(D) The first ionization potential of element (B) is less than the first ionization potential of element (A).

---

17 If you know that the third ionization potential of iron equals 2965 kJ/mol
then the third ionization potential of manganese is .....
(Sample exam 2025)

(A) 2389 kJ/mol (B) 2500 kJ/mol (C) 3250 kJ/mol (D) 2830 kJ/mol

---

18 (A) , (B) , (C) are elements of the first transition series, where :

- (A) : the densest element in the series.
- (B) : the element with the largest radius in the series.
- (C) : a non-transition element.

Which of the following choices is correct?
(2nd session 2024)

(A) (B) : does not react with dilute acids.

(B) (A) : one of its alloys is used in heating coils.

(C) (B) : reacts vigorously with water.

(D) (C) : has more than one oxidation state.

---

19 The opposite table shows the electron configuration of the cations of the elements (X) , (Y) , (Z) in their compounds :

X_2O_3 : $[_{18}Ar]$, $3d^3$, YO_2 : $[_{18}Ar]$, $3d^3$, Z_2O_3 : $[_{18}Ar]$, $3d^1$

then the correct order of these elements according to the effective charge of their nuclei is .....

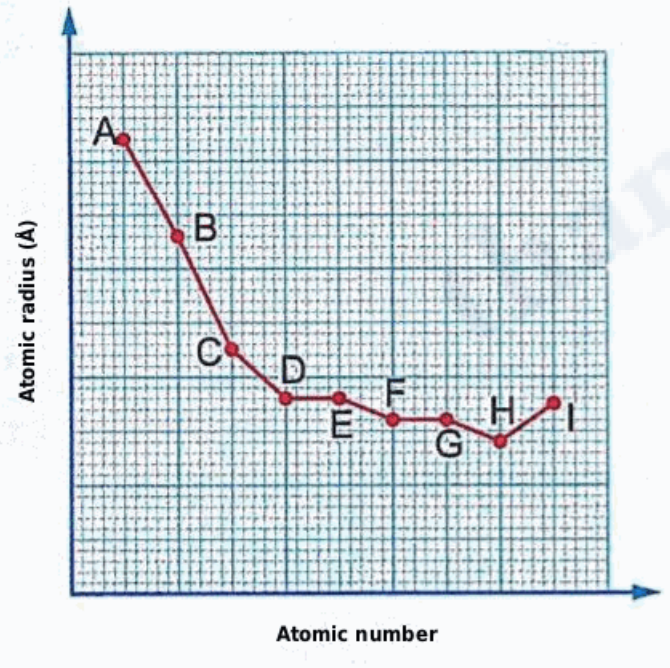
(2nd session 2023)

(A) X < Y < Z (B) Y < X < Z (C) X < Z < Y (D) Z < X < Y

20 The drawing in front of you shows the trend in the radius of the transition elements in the fourth period

The element that is irregular in atomic mass is .....

(2nd session 2022)

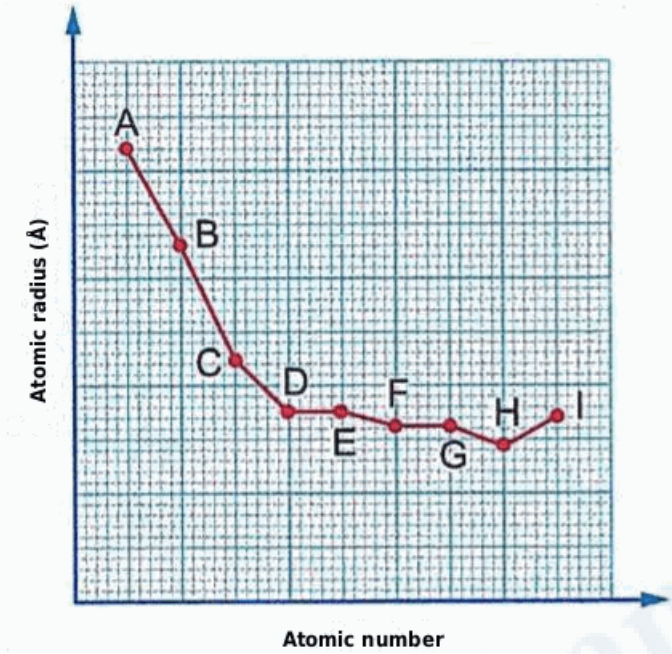


(A) C (B) H (C) E (D) D

21 The drawing in front of you shows the trend in the radius of the transition elements in the fourth period

The element one of whose oxides is used in making pigments is .....

(1st session 2022)



22 Which of the following choices is correct for the following transition elements?

$_{28}Ni$, $_{24}Cr$, $_{22}Ti$, $_{21}Sc$

(1st session 2024)

(A) Cr has the highest melting point and the lowest density of them.

(B) Sc has the highest atomic mass and boiling point of them.

(C) Ti has the lowest density and boiling point of them.

(D) Ni has the highest density and atomic mass of them.

23 The following statements describe properties of some elements of the first transition series. Which of them represents the densest element?

(Trial exam / March 2023)

(A) Its atomic mass is less than the atomic mass of the element before it.

(B) It has the largest magnetic moment in the atomic state.

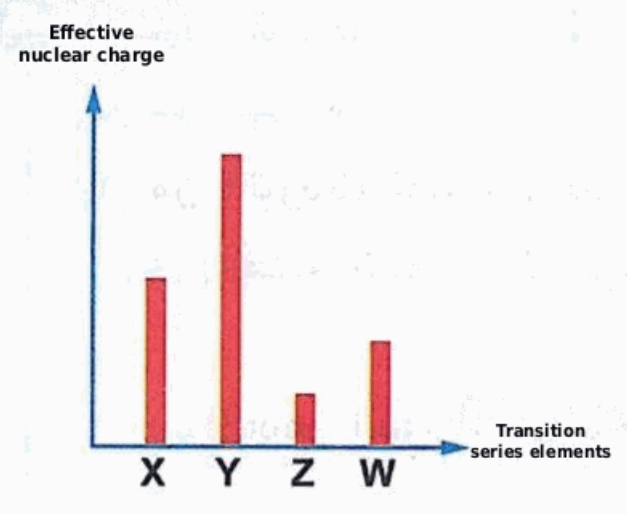
(C) Its 3+ ion is difficult to reduce to a 2+ ion

(D) The largest atomic size of the elements of the first transition series.

24 From the opposite graph :

Which of the following choices is correct?

(1st session 2023)



(A) Element (Z) is less dense than element (W).

(B) Element (Y) is less dense than element (Z).

(C) Element (W) has a higher ionization potential than element (X).

(D) Element (X) has a higher ionization potential than element (Y).

---

25 The elements (X) , (Y) , (Z) are successive transition elements at the end of the first transition series; the largest in atomic number is element (X), and they have the following compounds XA_2 , YA_2 , ZA_2

then the correct order according to the magnetic moment of their ions is .....

(1st session 2021)

(A) $Z^{2+} > Y^{2+} > X^{2+}$ (B) $X^{2+} > Y^{2+} > Z^{2+}$ (C) $Z^{2+} > X^{2+} > Y^{2+}$ (D) $X^{2+} > Z^{2+} > Y^{2+}$

---

26 A main transition element of the first transition series has the largest magnetic moment in its oxidation state $(2+)$.

Then the electron configuration of this element in the oxidation state $(3+)$ is .....

(2nd session 2022)

(A) $[_{18}Ar]$, $4s^0$, $3d^5$ (B) $[_{18}Ar]$, $4s^2$, $3d^5$ (C) $[_{18}Ar]$, $4s^0$, $3d^3$ (D) $[_{18}Ar]$, $4s^0$, $3d^4$

---

27 An element (X) whose electron configuration ends with the sublevel $3d^7$, so the compound XCl_3 has .....

(2nd session 2021)

(A) zero unpaired electrons.
(B) 2 unpaired electrons.
(C) 4 unpaired electrons.
(D) 3 unpaired electrons.

---

28 The elements (X) , (Y) , (Z) , (W) are of the first transition series :

(1) The cation of (XCl_2) has the lowest magnetic moment and element (X) has the highest atomic mass.

(2) The cation of (YCl_3) is paramagnetic and its highest oxidation state is +5

(3) The cation of (ZCl_2) is diamagnetic and Z is used in galvanizing metals.

(4) The cation of (WCl_3) has the highest magnetic moment and element (W) is of moderate chemical activity.

Deduce the names of each of the elements (X) , (Y) , (Z) , (W).

(2nd session 2024)

---

29 The opposite table shows the electron configuration of the cations of some elements; study it well, then answer :

A^{2+} : $[_{18}Ar]$, $3d^7$, B^{2+} : $[_{18}Ar]$, $3d^{10}$, C^{3+} : $[_{18}Ar]$, D^{4+} : $[_{18}Ar]$, $3d^3$

(1) From the cations of the opposite elements, deduce :

(a) the element that has the largest magnetic moment.

(b) the element that has the smallest magnetic moment.

(2) Which cation has an oxide used to lower the activation energy of the decomposition of $H_2O_2(l)$?

(2nd session 2023)

---

30 From the following compounds : VCl_5 , $CuSO_4$, $Fe_2(SO_4)_3$, $CrCl_3$

Which of the previous compounds is a compound :

(1) diamagnetic, whose cation is in the highest oxidation state.

(2) one of the compounds of its cation has a medical use, and it has the smallest magnetic moment.

(3) whose cation has the largest magnetic moment.

(4) paramagnetic, whose cation contains 3 unpaired electrons.

(1st session 2024)

---

31 (X) , (Y) are two elements of the first transition series :

• The oxide of element (X) is a catalyst in preparing oxygen.

• Element (Y) forms an alloy with element (X).

Deduce the cation that has the larger magnetic moment in the following oxides X_2O_3 , Y_2O_3 , and explain.

(Trial exam / March 2023)

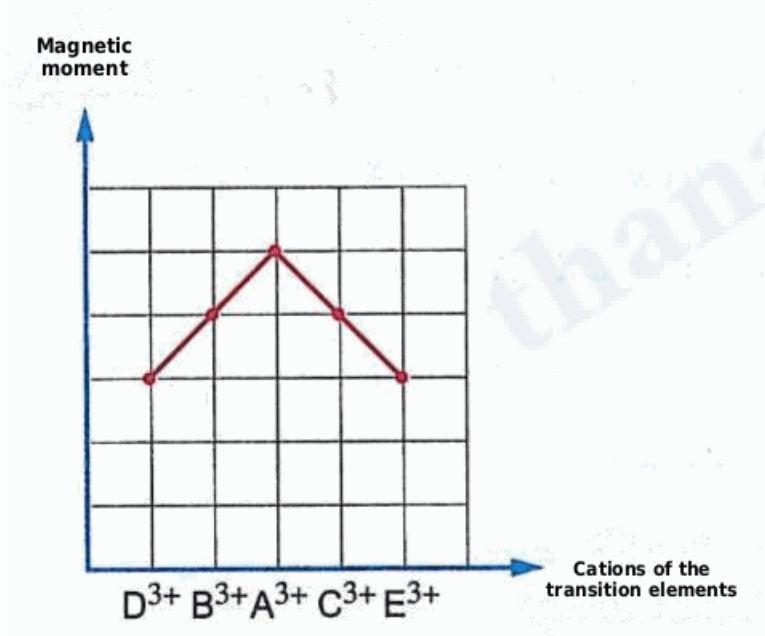
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32 The opposite graph shows the relation between the magnetic moment of some cations of the first transition series in order; deduce :

(1) the magnetic properties of the cations D^{6+} , B^{6+}

(2) the cations whose elements are used to lower the activation energy.

(1st session 2023)



Answer key and solutions

Multiple choice questions

1 D	2 C	3 B	4 D	5 A	6 B	7 D	8 B	9 A	10 D
11 B	12 B	13 B	14 D	15 B	16 A	17 A	18 A	19 D	20 C
21 C	22 A	23 B	24 C	25 C	26 B	27 B	28 A	29 A	30 B
31 D	32 C	33 D	34 A	35 A	36 B	37 B	38 B	39 D	40 C
41 D	42 D	43 C	44 C	45 D	46 D	47 B	48 D	49 C	50 A
51 D	52 D	53 D	54 B	55 B	56 B	57 B	58 C	59 A	60 C
61 C	62 C	63 C	64 C	65 B					

1 **Answer (D)**

As the atomic number increases in the period, the ionization energy increases, the radius decreases and the density increases

so oxidation becomes more difficult

2 **Answer (C)**

4s is half-filled in Cr ($4s^1\ 3d^5$) and Cu ($4s^1\ 3d^{10}$), and chromium is (X)

The oxidation states of chromium up to +6 equal its group number, but copper has +2 , which is greater than its group number (1)

so statement (C) is incorrect

3 **Answer (B)**

The effective nuclear charge increases as the atomic number increases

C is Cu (highest density), then A is Ni (smallest radius), then D is V (highest melting point), then B is Ti

4 **Answer (D)**

Fe^{2+} ($3d^6$) has 4 unpaired electrons, like Cr^{2+} ($3d^4$)

so (X) is iron and (Y) is chromium, and iron comes after chromium in the series

so the effective nuclear charge of iron is greater

5 **Answer (A)**

The numbers are (1) Cr , (2) Mn , (3) Co and (4) Ni

The atomic mass of cobalt (58.93) is greater than that of nickel (58.69)

so statement (A) is wrong

6 **Answer (B)**

Tanning leather: Cr , and the alloy with aluminium for soft-drink cans: Mn

Each of them has 5 electrons in 3d (Cr : $4s^1$ $3d^5$ and Mn : $4s^2$ $3d^5$)

while the unpaired electrons are 6 and 5 , so they differ

7 **Answer (D)**

The radii are close and the elements are successive

The density increases as the atomic mass increases, so the densest is the last element, (Z), i.e. copper

8 **Answer (B)**

Sc has one oxidation state (+3) and Zn has one state (+2)

9 **Answer (A)**

10 **Answer (D)**

11 **Answer (B)**

Density (g/cm^3): Sc ≈ 3 < V ≈ 6.1 < Co ≈ 8.90 < Ni ≈ 8.91

12 **Answer (B)**

(2) is copper, because Fehling's solution is made from its compounds

Copper is the least chemically active transition metal

13 **Answer (B)**

The element used to detect glucose is copper (Fehling's)

Its chemical activity is limited

14 **Answer (D)**

A transition element has a high density and a high melting point

(8.96 g/cm³ and 1085°C) are the values of copper

15 **Answer (B)**

X is iron (4 unpaired electrons, and Fe^{3+} 5)

Y is cobalt (3 unpaired electrons, and Co^{3+} 4)

Z is nickel (two unpaired electrons, and Ni^{3+} 3)

The atomic mass of cobalt (58.93) is greater than that of nickel (58.69)

16 **Answer (A)**

The density of V is about 6.1 g/cm³ , i.e. greater than 5

and V_2O_5 is a coloured compound (orange)

17 **Answer (A)**

The fourth for scandium breaks the stable [Ar] configuration, so it is greater

Iron is less because it loses an electron from $3d^5$

Scandium is more active, so it reacts with water faster than iron

18 **Answer (A)**

X is copper (highest density) , Y is vanadium (4 states: +2 to +5) , Z is chromium (highest melting point)

The effective nuclear charge increases with the atomic number: Cu > Cr > V

19 **Answer (D)**

Most transition metals form the +2 state (by losing the two 4s electrons)

so statement (D) is incorrect

20 **Answer (C)**

The cation of $CuNO_3$ is Cu^+ , with the configuration [Ar] $3d^{10}$ and no unpaired electrons

so it is diamagnetic

21 **Answer (C)**

Co^{2+} ($3d^7$) and Cr^{3+} ($3d^3$) have unpaired electrons, so they are paramagnetic

while Sc^{3+} and Zn^{2+} have no unpaired electrons

22 **Answer (A)**

Ti^{4+} has the configuration [Ar] with no unpaired electrons, so it is diamagnetic

Mn^{2+} , Fe^{2+} and V^{2+} have unpaired electrons

23 **Answer (B)**

The cation of CuF_2 is Cu^{2+} ($3d^9$), which has an unpaired electron, so it is paramagnetic and is attracted by the field

while Sc^{3+} , Zn^{2+} and Cu^{+} have no unpaired electrons, so they are repelled by it

24 **Answer (C)**

Cadmium Cd ($5s^2$ $4d^{10}$) and its ion Cd^{2+} ($4d^{10}$) have no unpaired electrons

so they are repelled by the magnetic field

25 **Answer (C)**

Substance (X) is a green solution that is attracted towards the magnet, so it is paramagnetic

Ni^{2+} and Cr^{3+} are green and have unpaired electrons

26 **Answer (B)**

The order of the moment follows the number of unpaired electrons: Mn^{2+} (5) > Fe^{2+} (4) > Co^{2+} (3) > Ni^{2+} (2)

so the order in (B) is reversed

27 **Answer (B)**

The apparent weight of paramagnetic substances increases

Fe^{3+} ($3d^5$) is paramagnetic

while Ti^{4+} , Mn^{7+} and Sc^{3+} have no unpaired electrons (diamagnetic)

28 **Answer (A)**

Zn^{2+} has the configuration [Ar] $3d^{10}$, so it is diamagnetic and statement (1) is correct

Zn loses the two 4s electrons, not 3d , so statement (2) is wrong

29 **Answer (A)**

Number of unpaired electrons: V^{4+} ($3d^1$) 1 , Ni^{2+} ($3d^8$) 2 , Mn^{4+} ($3d^3$) 3 , Fe^{3+} ($3d^5$) 5

30 **Answer (B)**

Number of unpaired electrons: Mn^{2+} 5 , Cr^{2+} 4 , V^{2+} 3 , Ti^{2+} 2

31 **Answer (D)**

X^{2+} is Zn^{2+} ($3d^{10}$) zero , Y^{2+} is Ti^{2+} ($3d^2$) two , Z^{2+} is Cu^{2+} ($3d^9$) one

so the order is X < Z < Y

32 **Answer (C)**

(X) is Cr and (Y) is Mn (the oxidizing salts $K_2Cr_2O_7$ and $KMnO_4$)

Cr^{3+} ($3d^3$) and Mn^{3+} ($3d^4$) are both paramagnetic

so their apparent weight increases in the field

33 **Answer (D)**

(1) Zn^{2+} is diamagnetic, so its apparent weight decreases slightly in the field

(2) Fe^{2+} is paramagnetic, so its apparent weight increases

34 **Answer (A)**

Not all ions of transition elements are paramagnetic

Sc^{3+} , Zn^{2+} and Cu^{+} , for example, are diamagnetic

35 **Answer (A)**

Co^{2+} has the configuration $3d^7$ with unpaired electrons, so it is paramagnetic

while Zn^{2+} , Ag^{+} and Cd^{2+} have the configuration d^{10} , so they are diamagnetic

36 **Answer (B)**

The magnetic moment is largest when there is the largest number of unpaired electrons

which is 5 at $3d^5$ (half-filled)

37 **Answer (B)**

$\mu = 5.9$ means $n(n+2) = 35$, i.e. $n = 5$

Fe^{3+} has the configuration $3d^5$ with 5 unpaired electrons

38 **Answer (B)**

The moment of the atom and the ion follow the number of unpaired electrons: Ni (2 unpaired) and Ni^{4+} ($3d^6$, 4 unpaired); its highest state +4 is less than the group number 10

Twice is achieved for nickel, and it has five stable isotopes

39 **Answer (D)**

The elements ending with 4s and 3d that give diamagnetic compounds in their highest oxidation state:

Sc (+3) , Ti (+4) , V (+5) , Cr (+6) , Mn (+7) and Zn (+2)

while Fe , Co , Ni and Cu keep unpaired electrons, so the number is 6

40 **Answer (C)**

The compound that blocks ultraviolet rays is ZnO , and its cation Zn^{2+} has a moment of zero

The cation of V_2O_5 is V^{5+} , with the configuration [Ar] , and its moment is also zero

41 **Answer (D)**

The element that reacts vigorously with water is Sc

Sc has only one oxidation state (+3), so it does not have many oxidation states

42 **Answer (D)**

The tenth ionization potential is very large, so the element has 9 valence electrons ($4s^2\ 3d^7$), and it is Co

It is used in magnets, has radioactive isotopes and is in group 9

The cobalt ions Co^{2+} and Co^{3+} all have unpaired electrons, so it has no diamagnetic compounds

43 **Answer (C)**

MnO_2 (Mn^{4+}) is a catalyst for the decomposition of H_2O_2

ZnO (Zn^{2+}) is used in cosmetics and rubber, and MnO_2 in the dry cell

so the other numbers +5 , +3 and +4 do not fit

44 **Answer (C)**

MnO_2 in the dry cell is an oxidizing agent (depolarizer), not a catalyst

45 **Answer (D)**

Atomic mass greater than the previous one, the +2 and +3 states and a catalyst: iron Fe

Iron is in group 8

46 **Answer (D)**

In the catalyst V_2O_5 , the oxidation state of vanadium is +5 , i.e. [Ar]

the same as in NH_4VO_3 (V^{+5}), while VO_2 (+4) , VN (+3) and VI_3 (+3) are different

47 **Answer (B)**

The seventh ionization potential is very large, so the element has 6 valence electrons, and it is chromium ($4s^1\ 3d^5$)

Chromium has an irregular configuration

48 **Answer (D)**

The contact process prepares H_2SO_4 and the catalyst is V_2O_5 , and the metal is vanadium V

The configuration of the V atom is [Ar] $3d^3\ 4s^2$

49 **Answer (C)**

The reason they are ideal catalysts is their many oxidation states and how easily they change, not losing the 4s electrons

50 **Answer (A)**

The element with a melting point of 3422°C and a density of 19.5 is tungsten W

Like other transition elements, it has catalytic activity

51 **Answer (D)**

52 **Answer (D)**

53 **Answer (D)**

The ninth potential is very large, so the element has 8 valence electrons ($4s^2\ 3d^6$), and it is iron

Iron is a catalyst in making ammonia (Haber–Bosch)

54 **Answer (B)**

A is Cr (6 unpaired) and B is Mn (it has more oxidation states)

$K_2Cr_2O_7$ is an oxidizing substance and MnO_2 is a catalyst in the decomposition of H_2O_2

55 **Answer (B)**

A is Mn , B is Cu (+2 exceeds its group number 1) , C is V

Boiling point: V > Cu > Mn

56 **Answer (B)**

The activation energy of the reaction without a catalyst: 130 kJ (from the reactants to the peak)

The reactants are higher than the products by 210 − 130 = 80 kJ

and the dotted peak is 180 kJ above the products

so the catalysed activation energy = 180 − 80 = 100 kJ

57 **Answer (B)**

Activation energy = the difference from the level of the reactants to the peak of the curve
which is (2) + (3)

58 **Answer (C)**

(1) is the energy level of the reactants
(3) is the difference between the energy of the reactants and the products, i.e. ΔH°

59 **Answer (A)**

In an exothermic reaction the energy of the products is less than that of the reactants, and the activation energy is from the reactants to the peak
and this is in figure (A)

60 **Answer (C)**

The uncatalysed reaction has the higher peak (the solid line)
and the activation energy is arrow C, from the level of the reactants to this peak
while B is for the catalysed reaction

61 **Answer (C)**

Ammonium sulphate needs sulphuric acid
and sulphuric acid is prepared by the contact process with the catalyst V_2O_5

62 **Answer (C)**

Car bodies need a light metal (low density) that is strong, tough and resistant to corrosion

63 **Answer (C)**

Oxidation state of V: VCl_3 (+3) , $VOSO_4$ (+4) , Na_3VO_4 (+5) and VSO_4 (+2)
so the highest state is in Na_3VO_4

64 **Answer (C)**

3 paired orbitals in 3d means $3d^8$, i.e. nickel Ni
Ni^{4+} has the configuration $3d^6$, like Fe^{2+} ($3d^6$)

65 **Answer (B)**

Most transition elements: high melting point, and their ions are paramagnetic (unpaired electrons) and their use as catalysts is common

Essay questions

1 **Model answer**

(1) The numbers of the two elements that can be magnetized are :

• (4) : iron.

• (5) : cobalt.

(2) • Both have lustre and shine (both are good conductors of electricity).

• They have the same atomic radius.

2 **Model answer**

(1) Mn^{3+} , Cr^{2+}

(2) The effective nuclear charge of Mn is greater than that of Cr, because the effective nuclear charge increases as the atomic number of the element increases.

3 **Model answer**

The metal (M) added to steel to make the alloy for car springs is vanadium V

(1) The atomic mass of the metal (M) (vanadium) is less than that of cobalt.

(2) The melting point of the metal (M) (vanadium) is higher than that of nickel.

4 **Model answer**

• Metal (X) : copper.

• Metal (Y) : vanadium.

• Metal (Z) : chromium.

(1) (Y) > (X) > (Z)

(2) (Y)

5 **Model answer**

The non-transition element : element (J).

The two reasons : • its melting point is low. • its density is low.

6 **Model answer**

The metal (M) : iron.

The reason :

• The $FeSO_4$ solution is paramagnetic, while the $Sc_2(SO_4)_3$ solution is diamagnetic.

• Iron reacts slowly with sulphuric acid, while scandium reacts quickly with sulphuric acid «a vigorous reaction».

«One reason only is enough».

7 **Model answer**

$2Cr + 3H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + 3H_2$

8 **Model answer**

(1) The net energy absorbed in the reaction (ΔH).

(2) The activation energy of the forward reaction.

9 **Model answer**

• In reaction (1) : H_2O_2 acts as a reducing agent, because it reduces the $KMnO_4$ solution, causing its colour to disappear.

• In reaction (2) : H_2O_2 acts as an oxidizing agent, because it oxidizes Fe^{2+} ions to Fe^{3+}

10 **Model answer**

The atomic number of the metal (M) = 18 + 5 + 3 = 26 , so the metal (M) is iron $_{26}Fe$

(1) Yes, the metal (M) can be magnetized.

(2) Yes, the radius of the metal (M) is equal to that of the metal after it in the period.

11 **Model answer**

• Metal (A) : cobalt Co

• Metal (B) : iron Fe

(1) Making magnets.

(2) The density of metal (A) is higher.

12 **Model answer**

$_{23}V : [Ar] , 3d^3 , 4s^2 \Longrightarrow V^{2+} : [Ar] , 3d^3$

$_{24}Cr : [Ar] , 3d^5 , 4s^1 \Longrightarrow Cr^{2+} : [Ar] , 3d^4$

$_{25}Mn : [Ar] , 3d^5 , 4s^2 \Longrightarrow Mn^{2+} : [Ar] , 3d^5$

$_{22}Ti : [Ar] , 3d^2 , 4s^2 \Longrightarrow Ti^{2+} : [Ar] , 3d^2$

(1) $Ti^{2+} < V^{2+} < Cr^{2+} < Mn^{2+}$

(2) Ti < V < Cr < Mn

Past exam questions

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

21	22	23	24	25	26	27	28	29	30
C	D	A	A	A	D	C	—	—	—

31	32
—	—

1 **Answer (C)**

X has the highest oxidation state $(+7)$, so it is Mn , and Y is Fe (or Cr before it)

Fe^{2+} $(3d^6)$ has 4 unpaired electrons, and so does Cr^{2+} $(3d^4)$, so the ion is paramagnetic

while Mn^{+3} has 4 unpaired and the Mn atom has 5 unpaired, so the other statements are wrong

2 **Answer (C)**

Two successive elements with the same number of 3d electrons, such as Cr and Mn $(3d^5)$ or Cu and Zn $(3d^{10})$

Adding a proton and a 4s electron hardly changes the radius (the effective nuclear charge balances the 3d repulsion)

so the radius is equal

3 **Answer (B)**

The magnetic strength increases as the number of unpaired electrons increases

Mn^{2+} (5) > Fe^{2+} (4) > Ti^{4+} (zero)

4 **Answer (C)**

(X): the fourth ionization potential is very large, so it has 3 valence electrons and it is aluminium (non-transition)

(Y): the sixth ionization potential is very large, so it has 5 valence electrons $(4s^2\ 3d^3)$ and it is vanadium (transition)

and the alloys of Y are used in railway rails

5 **Answer (C)**

The element similar to the one before and the one after it in the same group is cobalt (Fe , Co and Ni are in group VIII)

Co^{3+} $(3d^6)$ is easily oxidized to the half-filled Co^{4+} $(3d^5)$

6 **Answer (C)**

(X) is vanadium $(3$ unpaired electrons) and (Y) has 6 unpaired, so it is chromium

The highest oxidation state of chromium is +6 , which is higher than +5 for vanadium

7 **Answer (D)**

(X) is V (V_2O_5 in the contact process) and it has 3 unpaired electrons

(Y) is not next to it and has 3 unpaired, so it is Co ($4s^2\ 3d^7$)

The atomic mass of cobalt (58.93) is greater than that of nickel (58.69), which comes after it

8 **Answer (D)**

(A) is the irregular chromium, then (B) Mn , then (C) Fe

Cr^{3+} ($3d^3$) 3 unpaired , Mn^{3+} ($3d^4$) 4 unpaired , Fe^{3+} ($3d^5$) 5 unpaired

so the moment: C > B > A

9 **Answer (D)**

(X) is chromium (resists weather conditions) and (Y) is manganese (both $3d^5$)

The effective nuclear charge increases with the atomic number, so it is greater in Mn

10 **Answer (D)**

X is Mn (pairing begins after it), Y is Fe (the first element that does not lose all its electrons), Z is Cu and W is Cr

The change X_2O_3 to XO is Mn^{3+} ($3d^4$) to Mn^{2+} (half-filled $3d^5$), i.e. more stable and lower in energy

while Fe^{3+} to Fe^{2+} loses stability

11 **Answer (B)**

A is Cr (the number of unpaired is 6 , then 4 in Cr^{2+})

C is Mn (5 unpaired in Mn^{2+} , then 4 in Mn^{3+} , and its radius is close to chromium)

B is an element whose number of unpaired electrons increases at +3 , such as Fe

Density: Cr < Mn < Fe

12 **Answer (C)**

B^{3+} has the configuration $3d^3$, so it is Cr , and A is V , C is Mn and D is Fe

Mn^{2+} ($3d^5$) to Mn^{3+} ($3d^4$): the number of unpaired electrons decreases, so the moment decreases

while for Fe^{2+} to Fe^{3+} the number of unpaired electrons increases

13 **Answer (A)**

X^{2+} has 11 filled orbitals and 3 half-filled ones: [Ar] $3d^7$, so it is Co

The atomic mass of cobalt (58.93) is greater than that of nickel (58.69), which comes after it

so statement (A) does not describe it

14 **Answer (A)**

Ni (58.69) , Co (58.93) and Cu (63.5): the order Y < Z < X means Y = Ni , Z = Co and X = Cu

Moment: Co^{2+} (3 unpaired) > Ni^{2+} (2) > Cu^{2+} (1)

15 **Answer (B)**

The magnetic moment of chromium is the highest in the series (6 unpaired electrons)

and when it changes to Cr^{2+} ($3d^4$) it decreases to 4 unpaired

16 **Answer (B)**

A is Sc , B is Cr , C is Co and D is Ni

The mass of Ni (58.69) is less than that of Co (58.93), and this is an irregularity

17 **Answer (C)**

Fe^{3+} forms the half-filled $3d^5$, so the third ionization potential of iron is lower

$Mn^{2+} \rightarrow Mn^{3+}$ breaks $3d^5$, so the third ionization potential of manganese is greater than 2965 ,

and it is 3250

18 **Answer (C)**

A is copper (highest density), B is Sc (largest radius) and C is Zn

Sc is very active, so it reacts vigorously with water

19 **Answer (D)**

X^{3+} ($3d^3$) is Cr , Y^{4+} ($3d^3$) is Mn , Z^{3+} ($3d^1$) is Ti

The effective charge increases with the atomic number: Ti (22) < Cr (24) < Mn (25)

20 **Answer (B)**

The points from A to I are Sc , Ti , V , Cr , Mn , Fe , Co , Ni , Cu

Nickel (H) has a smaller mass than cobalt before it, and this is the irregularity

21 **Answer (C)**

Chromium oxide Cr_2O_3 is used in pigments

and chromium is the fourth in the series (D)

22 **Answer (D)**

Ni has the highest density and atomic mass among the elements mentioned

while the lowest density is for Sc , and the highest melting point is for chromium

23 **Answer (A)**

Ni has an atomic mass (58.69) less than Co before it (58.93), and it is the densest among the choices

while Cr has the largest moment, Fe^{3+} is difficult to reduce to Fe^{2+} and Sc has the largest size

24 **Answer (A)**

The effective charge increases as the atomic number increases

Z has the lowest effective charge, so it has a smaller atomic number than W and its density is lower

25 **Answer (A)**

The successive elements are Cu , Ni and Co , with Cu^{2+} ($3d^9$) , Ni^{2+} ($3d^8$) and Co^{2+} ($3d^7$)

The number of unpaired electrons is 1 , 2 and 3 , respectively

so the moment: Z > Y > X

26 **Answer (D)**

The largest moment in +2 is Mn^{2+} ($3d^5$)

In +3 it loses another electron from 3d and becomes [Ar] $3d^4$

27 **Answer (C)**

The element with $3d^7$ is Co

In $CoCl_3$ the ion Co^{3+} has the configuration [Ar] $3d^6$ and has 4 unpaired electrons

28 **Model answer**

- Element (X) : copper.
- Element (Y) : vanadium.
- Element (Z) : zinc.
- Element (W) : iron.

29 **Model answer**

(1) (a) Element D

(b) Element B

(2) D^{4+}

30 **Model answer**

(1) VCl_5

(2) $CuSO_4$

(3) $Fe_2(SO_4)_3$

(4) $CrCl_3$

31 **Model answer**

• Element (X) : manganese.

• Element (Y) : iron.

$_{25}Mn$: [Ar] , $3d^5$, $4s^2 \Longrightarrow Mn^{3+}$: [Ar] , $3d^4$

$_{26}Fe$: [Ar] , $3d^6$, $4s^2 \Longrightarrow Fe^{3+}$: [Ar] , $3d^5$

Y^{3+} has a larger magnetic moment than X^{3+} , because Y^{3+} contains 5 unpaired electrons in the 3d sublevel, more than X^{3+} , which contains 4 unpaired electrons in the 3d sublevel

32 **Model answer**

(1) D^{6+} : diamagnetic.

B^{6+} : paramagnetic.

(2) A^{3+} (Fe) , E^{3+} (Ni)