Oxidation Numbers in Transition Metals Worksheet (Includes Answers)

Resources:
www.youtube.com/watch?v= PEJt3VMfiPA
www.somethingcalledscience.com/post/oxidation-numbers-in-transition-metals

Oxidation Numbers in Transition Metals - Worksheet

Part 1: Vocabulary and Concepts

Define the following terms in your own words:

1. Oxidation number:
2. Transition metal:
3. d orbital:
4. Stock system:

Part 2: Multiple Choice

Circle the correct answer:

5. When an atom loses electrons, its oxidation number becomes:
   - a) Negative
   - b) Positive
   - c) Zero
   - d) Neutral
6. What makes transition metals different from regular elements like sodium or chlorine?
   - a) They are heavier
   - b) They can have multiple oxidation numbers
   - c) They only exist in laboratories

- d) They cannot form compounds

7. In the compound Iron(III) chloride, what is the oxidation number of iron?

- a) +1
- b) +2
- c) +3
- d) -3

8. The green patina on old copper structures is which compound?

- a) Copper(I) oxide
- b) Copper(II) carbonate
- c) Copper(III) chloride
- d) Pure copper

Part 3: Naming Compounds

Write the correct name for each compound using the Stock system (Roman numerals):

9. $FeCl_2$ (iron has oxidation number +2): _____

10. $FeCl_3$ (iron has oxidation number +3): _____

11. CuO (copper has oxidation number +2): _____

12. Cu_2O (copper has oxidation number +1): _____

Part 4: Short Answer

13. Explain why transition metals can have multiple oxidation numbers while elements like sodium typically have only one.

14. What are the three basic rules for determining oxidation numbers mentioned in the text?

- Rule 1:
- Rule 2:
- Rule 3:

15. Give one real-world example of why understanding oxidation numbers is important.

Part 5: Calculating Oxidation Numbers

Solve for the oxidation number of the transition metal in each compound. Show your work!

16. **FeO** (iron oxide)

- Let iron's oxidation number = x
- Oxygen's oxidation number =
- Equation:
- Solution: x =

17. **MnO_2** (manganese dioxide)

- Let manganese's oxidation number = x
- Oxygen's oxidation number =
- Equation:
- Solution: x =

18. **Cr_2O_3** (chromium oxide)

- Let chromium's oxidation number = x
- Oxygen's oxidation number =
- Equation:
- Solution: x =

19. **Dichromate ion: $Cr_2O_7^{2-}$**

- Let chromium's oxidation number = x
- Oxygen's oxidation number =
- Equation:
- Solution: x =

Part 6: Matching

Match the older naming system with the modern Stock system:

20. Ferrous _____ a) Iron(III)

21. Ferric _____ b) Copper(II)

22. Cuprous _____ c) Iron(II)

23. Cupric _____ d) Copper(I)

Part 7: Critical Thinking

24. The text mentions that chromium(III) is safe but chromium(VI) is dangerous. Why would these two forms of the same element have such different effects on human health?

25. Explain how iron's ability to change oxidation states is essential for breathing.

26. Why is the Roman numeral system (Stock system) preferred over the older -ous/-ic naming system?

Challenge Problems

27. **Potassium permanganate: $KMnO_4$**

- Potassium's oxidation number = +1
- Oxygen's oxidation number = -2
- Find manganese's oxidation number:

28. **Iron(II) sulfate: $FeSO_4$**

- If the sulfate ion (SO_4^{2-}) has a total charge of -2, and iron is +2, verify that the compound is electrically neutral. Explain your reasoning.

Bonus Question

29. Research and name one transition metal compound not mentioned in the text. State the metal's oxidation number and describe one use for this compound.

ANSWER KEY

Part 1: Vocabulary and Concepts

1. **Oxidation number:** A bookkeeping system for electrons that tells us how many electrons an atom has gained, lost, or is sharing in a chemical compound.
2. **Transition metal:** Elements in the middle section of the periodic table (like iron, copper, manganese) that can have multiple oxidation numbers because they can lose electrons from both their outermost shell and from d orbitals.
3. **d orbital:** Special "parking spaces" for electrons that are close enough in energy to the outermost electrons that they can also participate in chemical reactions, giving transition metals the ability to have multiple oxidation states.
4. **Stock system:** The modern naming system that uses Roman numerals in parentheses to indicate the oxidation number of a transition metal in a compound.

Part 2: Multiple Choice

5. **b) Positive**
6. **b) They can have multiple oxidation numbers**
7. **c) +3**
8. **b) Copper(II) carbonate**

Part 3: Naming Compounds

9. **Iron(II) chloride**
10. **Iron(III) chloride**
11. **Copper(II) oxide**
12. **Copper(I) oxide**

Part 4: Short Answer

13. Transition metals have electrons in d orbitals, which are close enough in energy to the outermost electrons that they can also participate in chemical reactions. Regular elements typically only lose or gain electrons from their outermost shell, but transition

metals can lose electrons from both their outermost shell and from d orbitals, giving them multiple options for how many electrons to give up.

14. **The three basic rules:**

- Rule 1: In any compound, all the oxidation numbers must add up to zero
- Rule 2: Oxygen is almost always -2
- Rule 3: Hydrogen is almost always +1

15. **Possible answers include:**

- Iron in blood changes oxidation states to carry oxygen from lungs to muscles
- Catalytic converters use transition metals to clean car exhaust
- Environmental cleanup: converting toxic chromium(VI) to safe chromium(III)

Part 5: Calculating Oxidation Numbers

16. **FeO**

- Let iron's oxidation number = x
- Oxygen's oxidation number = -2
- Equation: x + (-2) = 0
- Solution: x = **+2**

17. **MnO_2**

- Let manganese's oxidation number = x
- Oxygen's oxidation number = -2
- Equation: x + 2(-2) = 0 → x - 4 = 0
- Solution: x = **+4**

18. **Cr_2O_3**

- Let chromium's oxidation number = x
- Oxygen's oxidation number = -2
- Equation: 2x + 3(-2) = 0 → 2x - 6 = 0 → 2x = 6
- Solution: x = **+3**

19. **$Cr_2O_7^{2-}$**

- Let chromium's oxidation number = x
- Oxygen's oxidation number = -2
- Equation: 2x + 7(-2) = -2 → 2x - 14 = -2 → 2x = 12
- Solution: x = **+6**

Part 6: Matching

20. Ferrous **c)** Iron(II)

21. Ferric **a)** Iron(III)

22. Cuprous **d)** Copper(I)

23. Cupric **b)** Copper(II)

Part 7: Critical Thinking

24. Different oxidation states have different electron arrangements, which changes how the compounds interact with biological molecules and cells. The different chemical behaviors and properties of chromium(III) versus chromium(VI) mean they react differently with living tissue—chromium(VI) is more reactive and can damage DNA and cells, while chromium(III) is stable and even necessary in trace amounts.

25. Iron in hemoglobin switches between +2 and +3 oxidation states. This allows it to grab oxygen molecules in the lungs (when oxygen binds to iron) and release oxygen to muscles and organs. Without this ability to change oxidation states, iron couldn't reversibly bind and release oxygen.

26. The Roman numeral system is clearer and works for metals with more than two oxidation states. The old -ous/-ic system only has two endings (for lower and higher states), so it runs out of options for metals like manganese that can have many different oxidation numbers (ranging from +2 to +7).

Challenge Problems

27. **$KMnO_4$**

    - Potassium: +1
    - Oxygen: -2
    - Equation: $(+1) + x + 4(-2) = 0 \rightarrow 1 + x - 8 = 0 \rightarrow x = +7$
    - **Manganese's oxidation number = +7**

28. **$FeSO_4$ verification:**

    - Iron: +2
    - Sulfate ion: -2
    - Total: $(+2) + (-2) = 0$

- The compound is electrically neutral because the positive charge from iron(II) exactly balances the negative charge from the sulfate ion, resulting in a net charge of zero.

Bonus Question

29. **Answers will vary.** Examples include:
- Titanium(IV) oxide (TiO_2): Used in sunscreen and white paint
- Silver(I) nitrate ($AgNO_3$): Used in photography and as an antiseptic
- Nickel(II) chloride ($NiCl_2$): Used in electroplating
- Vanadium(V) oxide (V_2O_5): Used as a catalyst in sulfuric acid production