World Journal of Chemical Education, 2017, Vol. 5, No. 5, 168-174
Available online at http://pubs.sciepub.com/wjce/5/5/5
DOI:10.12691/wjce-5-5-5

Designing Experimental Exercises Used for Teaching Chemistry in High School

C.C. Giac[1,*], L.H. Hoang[2], N.T.P. Lien[3], P.H. Thanh[4]

[1]Faculty of Chemistry, Vinh University, Vinh City, Vietnam
[2]Faculty of Chemistry, Dong Thap University, Dong Thap Province , Vietnam
[3]Faculty of Environmental Science, Saigon University, Ho Chi Minh City, Vietnam
[4]Nguyen Duc Mau High School, Nghe An Province, Vietnam
*Corresponding author: giaccc@vinhuni.edu.vn

Abstract This study has represented a model of experimental exercises in teaching chemistry. The model, which is the type of exercise associated with chemistry laboratories that when students answer them, they have to get the basic skills of practice chemistry. By analyzing the model of experimental exercises, we have proposed two underpinnings to design these exercises. On that basic, we proposed the way to design new experimental exercises. These methods are analyzed in detail and there are the attached application so that teacher can apply to design the same cases. Based on the proposed methods, we have designed sample exercises used in high school chemistry teaching. The exercises were solved clearly and evaluation of chemistry practical skills for students. This type of exercises is always attractive to create certain excitements for teachers and students in the teaching and learning chemistry in high school.

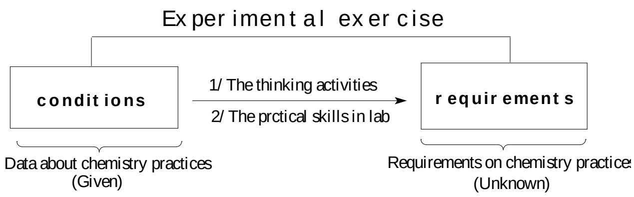
Keywords: *teaching chemistry, experimental exercises, chemistry practical skills, laboratory*

Cite This Article: C.C. Giac, L.H. Hoang, N.T.P. Lien, and P.H. Thanh, "Designing Experimental Exercises Used for Teaching Chemistry in High School." *World Journal of Chemical Education*, vol. 5, no. 5 (2017): 168-174. doi: 10.12691/wjce-5-5-5.

1. Introduction

1.1. Model of Experimental Exercises of Chemistry

Chemistry experimental exercises are problems that students have to apply their practised knowledge in the laboratory when they answer them. Model of experimental exercises below.



1.2. Underpinnings of Designing Chemistry Experimental Exercises

From the model above, we infered 2 underpinnings for designing practical exercises of chemistry [1].

Theoretical underpinning: including the contents of chemistry theory [2].

Experimental underpinning: including the experimental contents and practicing skills in the lab [3].

Thus, in order to design experimental exercises may stem from:

(1) The basic knowledge and practicing skills to train for students [4].

(2) Common mistakes of theory and practice that students often make.

(3) Some basic exercises available.

Based on the underpinnings and the starting point above, we can build an chemistry experimental exercise with typical basic properties (called as the *original exercise*). Applying grap method combined with the modular approach, we can modify the original exercise into some different exercises based on some fundamental principles below.

Principle 1: Inverse between conditions and requirements

Principle 2: Change conditions

Principle 3: Change requirements

Principle 4: Change both conditions and requirements

Principle 5: Combination several exercises

Principle 6: Transfer essay exercises (short answer or extended response) to multiple choice test and vice versa.

2. Method - Designing Exercises

We can consider an example for teaching halogen chapter of inorganic chemistry. After students have completed this chapter, teachers should check students' practical skills of collecting chlorine gas in the laboratory. Teachers can build the following original exercise.

Original exercise: In the laboratory, chlorine gas is often prepared from MnO_2 and concentrated HCl acid [5].

a) Write the chemical equation for this reaction.

b) Was chlorine gas obtained above pure or not?

In this exercise, teachers can test students' knowledge about the preparation and collecting of dry chlorine gas in lab. The chemical equation for the reaction is shown below.

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

From the equaition, students will recognize the obtained chlorine gas is not pure because of containing a small amount of hydrogen chloride gas and water vapor.

Applying in turn 6 principles above, at least we can design 6 derivative exercises stem from the original exercise [8]. For example:

Apply principle 1: In laboratory, chlorine gas is formed from the following reaction

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

If chlorine gas prepared directly from the reaction, product is not pure. Give an explaination.

Apply principle 2: In the laboratory, chlorine gas is often prepared from MnO_2 and conc. HCl acid. Sometimes, we need to use a dry gas in an experiment. To collect clean and dry chlorine gas, obtained gas can go through the gas washing bottles A and B (Figure 1). Which substance will the gas washing bottles A and B contain in the following substances: $Ca(OH)_2$ solution, NaOH solution, NH_3 solution, NaCl solution, Br_2 solution, conc. H_2SO_4 acid and H_2O? Explain that choice.

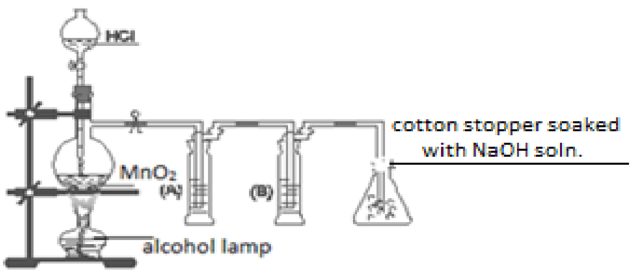


Figure 1. Collecting pure chlorine gas

Solution: Obtained gases consist of chlorine, hydrogen chloride and water vapor. We infer the gas washing bottle A containing NaCl solution (removing hydrogen chloride) and the gas washing bottle B containing conc. H_2SO_4 acid (drying agent).

Apply principle 3: In the laboratory, chlorine gas is often prepared from MnO_2 and conc. HCl acid.

a) Write the chemical equation for this reaction.

b) Analyzing incorrect points when set up the apparatus shown in Figure 2 below.

Solution: In this exercise, requirements have been complicated, students will write the chemical equation for the reaction below.

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

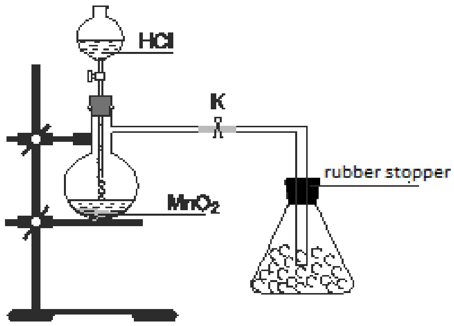


Figure 2. The apparatus was used to prepare chlorine gas

In terms of practical skills, teachers need to analysis for student understanding experimental illustrations, students inferred in this experiment:

- Chlorine gas is collected by displacement of air – downward delivery because it is soluble in water and denser than air.

- Chlorine gas is collected by displacement of air – downward delivery, so we should not use the rubber stopper as Figure 2 above. Replace the rubber stopper with cotton button soaked with NaOH solution.

- In order to collect the pure gas of chlorine, we need to carry out additional installation gas washing bottles as shown in Figure 1.

- This reaction occurs only when heated so we need to use an alcohol lamp to provide heat as shown in Figure 1.

Apply principle 4: A student set up an experimental instrument to prepare and collect chlorine gas in lab as Figure 3 below.

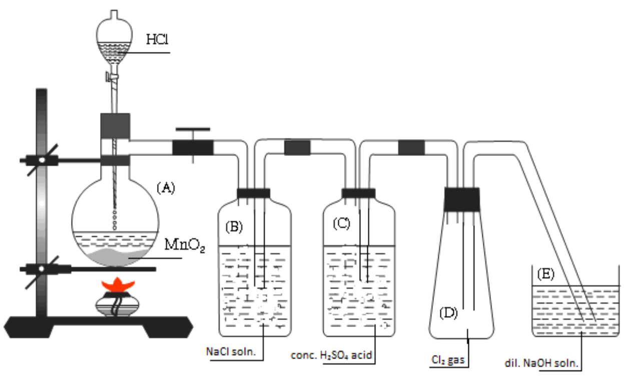


Figure 3. The apparatus was used to prepare and collect chlorine gas

a) Indicates the function of the flasks (A), (B), (C) and (D)?

b) Analysis some unreasonable things in Fig. 3 above. Explain and reassemble the apparatuses exactly.

Solution: In this exercise, both the conditions and requirements have been complicated, teachers should guide students analyze:

a) Flask A contains reaction mixture:

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

Students deduce the gas products containing a small amount of hydrogen chloride gas and water vapor. So the flask B is used for washing gas, the flask C is used for drying gas, the flask D is used for collecting gas and the flask E is used for eliminating residual chlorine gas.

b) From features of the above flasks, indicating laboratory apparatuses are not reasonable:

- The tube introducing the gas from the flask A has to immerse deeply in the NaCl solution (inside flask B) so that hydrogen chloride gas is readily soluble in salt solution. Second delivery tube of flask B has to be shorter placed and not touch the NaCl solution so that chlorine gas goes into flask C easily and not push NaCl solution into the flask C.

- Similarly, left delivery tube of the flask C has to immerse deeply in H_2SO_4 solution (removing water vapor) and right delivery tube has to be shorter placed (not touch the H_2SO_4 acid) so that chlorine gas goes into flask D easily and H_2SO_4 solution is not pushed into the flask D.

- The left delivery tube of the flask D has to be designed longer than the right delivery tube because it only has a task that is treatment the residual chlorine gas in the flask D when it was fully collected.

The apparatus should be set up as Figure 4 below.

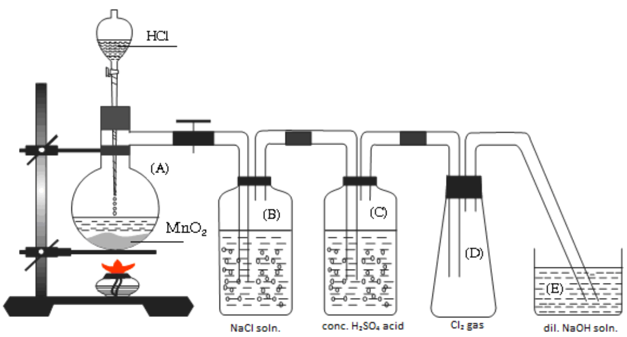


Figure 4. The apparatus was used to prepare and collect chlorine gas

Apply principle 5: In the laboratory, the apparatus is installed to prepare and collect C gas as shown in Figure 5. The flask A in which contained solid and the funnel B contained liquid.

a) Indicate C gas is denser or less dense than air?

b) What is the gas C if A is MnO_2 and B is conc. HCl acid?

c) Explain the phenomenon that occurs when the lock K closed and opened.

d) How to remove a residual C gas in the lab? Write the chemical equation if available.

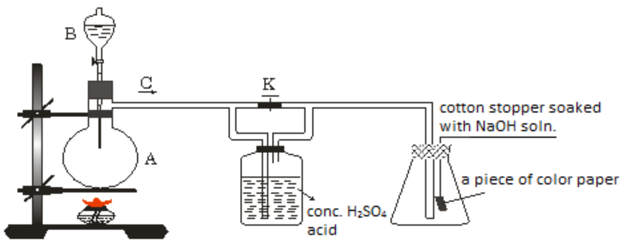


Figure 5. The apparatus was used to prepare and test the gas properties

Solution: This exercise is a combination of many different exercises, which increases the complexity of the conditions and requirements. Teachers can guide students analyzed as follows:

a) Downward delivery should be used to collect gases that are denser than air, such as chlorine and hydrogen chloride.

b) A is MnO_2 and B is conc. HCl acid so easily inferred C is chlorine gas.

$$MnO_2(s) + 4HCl(conc.) \xrightarrow{heat} MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

c) When the lock K closes, chlorine gas is dried by concentrated H_2SO_4 acid so it can not bleach color paper. When the lock K opens, fresh chlorine gas containing a small amount of steam so it has bleaching properties (due to oxidizing agent HClO) and color paper was bleached.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HClO(aq)$$

d) Ammonia gas is sprayed into the lab and closed the door and windows in 15 minutes, then opened the door and cleaned up the room.

$$2NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6HCl(g)$$
$$6NH_3(g) + 6HCl(g) \longrightarrow 6NH_4Cl(s)$$
$$8NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6NH_4Cl(s)$$

Apply principle 6: To collect the chlorine gas in the laboratory, which can you do in the following ways?

A. Collecting directly by means of pushing the air.

B. Collecting over hot water.

C. Collecting over saturated NaCl solution.

D. All 3 ways of the above.

Solution: In this exercise, in spite of the objective test, but students want to answer this exercise, they have to know the properties of chlorine gas, namely:

- Chlorine gas is denser than air, it can be collected directly by displacement of air with downward delivery.

- Chlorine gas is less soluble in hot water, because the following equilibrium shifts to the left:

$$Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HClO(aq), \Delta H < 0.$$

In a saturated NaCl solution, chlorine gas is also very slightly soluble so the above equilibrium shifts to the left.

Thus all three methods will be able to collect chlorine gas (Answer D).

Test Yourself

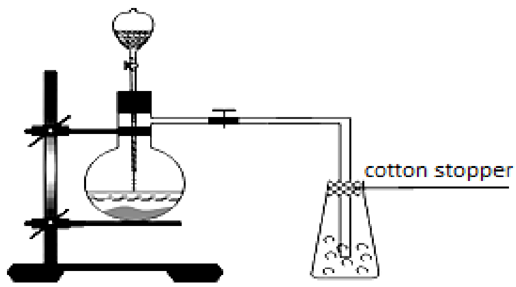
1. Which gases was the apparatus shown used to collect in the laboratory [8]?

A. Cl_2, O_2 and CO_2

B. Cl_2, O_2 and NH_3

C. CO_2, NO and NH_3

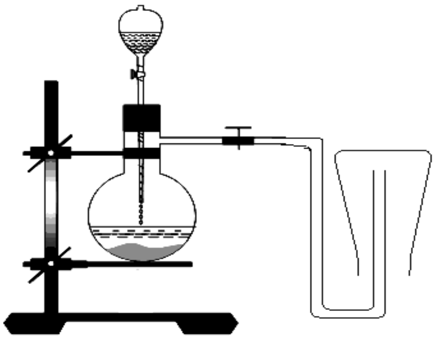
D. Cl_2, O_2, NO, CO_2 and NH_3



Answer A.

2. Which gases was the apparatus shown used to collect in the laboratory?

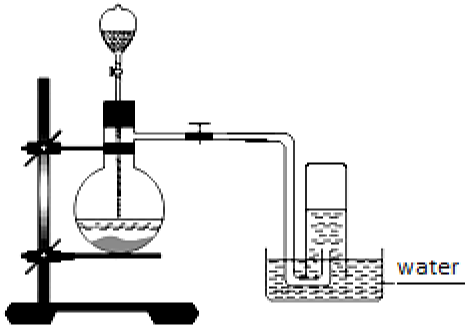
A. CO_2 and H_2
B. NH_3 and H_2
C. CO_2 and NO_2
D. NO_2 and NH_3



Answer B.

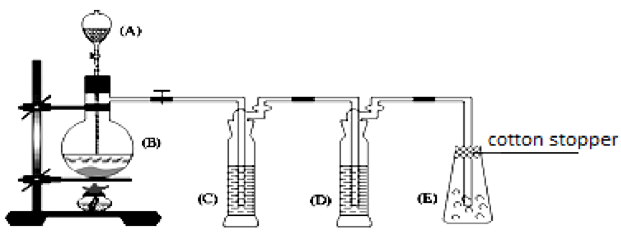
3. Which gases was the apparatus shown used to collect in the laboratory?

A. O_2 and NH_3
B. NO and HCl
C. NH_3 and HCl
D. O_2 and NO



Answer D.

4. In the laboratory for the preparation and collection of some pure gases, people set up experimental kits as shown below.



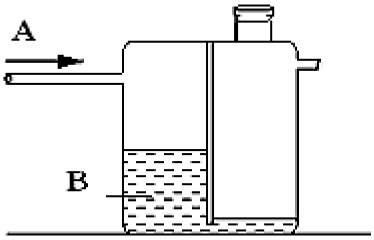
Flask (A): Containing liquid or solution.
Flask (B): Containing solid or solution.
Flask (C): Containing liquid or solution.
Flask (D): Containing solution or solid (Tisenco Flask).
Flask (E): Collecting gas.

Above apparatus can be used to prepare and collect which gases of the following gases?

A. Cl_2, HCl, H_2S, SO_2, NO_2, CO_2
B. SO_2, NO_2, NH_3, CO, CO_2
C. HCl, H_2S, SO_2, NO_2, CH_4
D. O_2, Cl_2, H_2, HCl, H_2S

Answer A.

5. Figure below simulated image was observed when the A gas passes through a gas washing bottle containing B liquid.



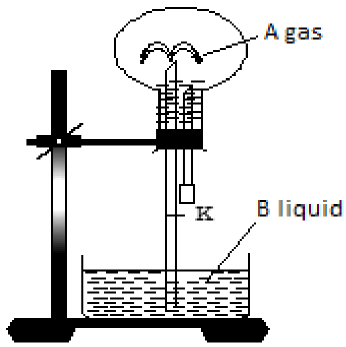
A and B substances in the experiment above is

A. A is NH_3, B is H_2O
B. A is HCl, B is C_2H_5OH
C. A is CH_4, B is H_2O
D. A is O_2, B is H_2O

Answer A.

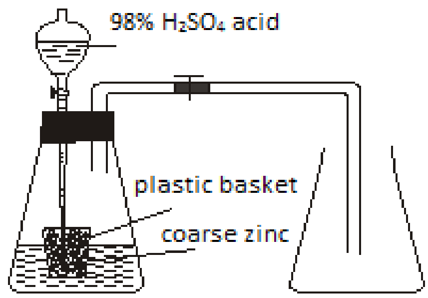
6. Carry out an experiment as shown below: Flask contains A gas inserted a delivery tube into the beaker containing B liquid. When unlocked K, liquid of B sprayed into the flask. If liquid B is the solution Br_2 in CCl_4 which gas is A gas in the following gases?

A. SO_2
B. C_2H_4
C. H_2S
D. NH_3



Answer B.

7. A student set up the apparatus to prepare hydrogen gas by Kipp gas generator in the laboratory as shown below.

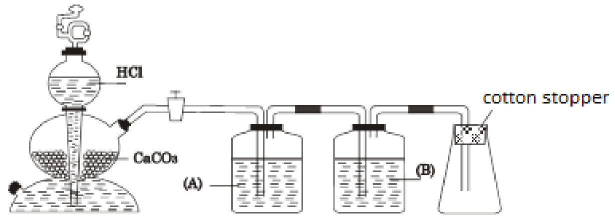


Observation on the above apparatus can indicate how many mistakes made hydrogen gas can not be collected in a laboratory?

A. 1
B. 2
C. 3
D. 4

Answer B.

8. In the laboratory, carbon dioxide gas is often prepared from $CaCO_3$ and HCl acid (the following figure) thus containing a small amount of hydrogen chloride gas and water vapor.



To collect pure carbon dioxide gas, product can be gone through 2 flasks (A) and (B) contain which substances in the following substances?

A. Vessel (A) contains $NaHCO_3$ solution and vessel (B) contains conc. H_2SO acid.

B. Vessel (A) contains conc. H_2SO_4 acid and vessel (B) contains $NaHCO_3$ solution.

C. Vessel (A) contains $NaHCO_3$ solution and vessel (B) contains conc. HNO_3 acid.

D. Vessel (A) contains conc. HNO_3 acid and vessel (B) contains $NaHCO_3$ solution.

Answer A.

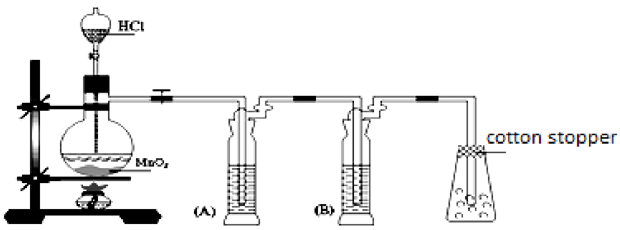
9. In the laboratory, chlorine gas is often prepared from MnO_2 and conc. HCl acid. To collect clean and dry chlorine gas, obtained gas can go through the gas washing bottles A and B as shown below. Which substance will the gas washing bottles A and B contain in the following substances?

A. Vessel (A) contains $Ca(OH)_2$ solution and vessel (B) contains NH_3 solution.

B. Vessel (A) contains $Ca(OH)_2$ solution and vessel (B) contains conc. H_2SO_4 acid.

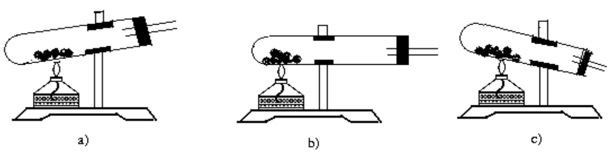
C. Vessel (A) contains $KMnO_4$ solution and vessel (B) contains conc. H_2SO_4 acid.

D. Vessel (A) contains conc. H_2SO_4 acid and vessel (B) contains $KMnO_4$ solution.



Answer C.

10. There are 3 students who carry out to prepare O_2 by pyrolysis reaction of potassium permanganate in the test tube which is set up as shown below (a, b, c).



The way to set up the test tube in according to which figure is correct?

A. a)

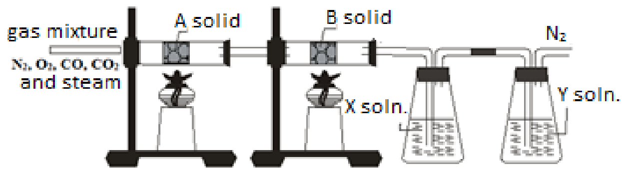
B. b)

C. c)

D. a), b) and c).

Answer C.

11. To collect pure nitrogen gas from the gas mixture of N_2, O_2, CO, CO_2 and water vapor, the gas mixture passes in turn through the substances A, B, X and Y, as shown below.



The substances A, B, X and Y are respective

A. Cu, CuO, NaOH soln. and conc. H_2SO_4 acid.

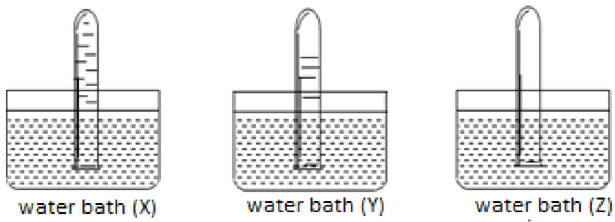
B. Cu, CuO, conc. H_2SO_4 acid and NaOH soln.

C. CuO, Cu, NaOH soln. and conc. HCl acid.

D. CuO, Cu, conc. HCl acid and NaOH soln.

Answer A.

12. There are 3 gases (N_2, H_2S, HCl) contained in 3 test tubes which were turned upside-down in 3 water baths as shown below.



Gas in the test tubes which were turned upside down in 3 water baths X, Y, Z respectively

A. N_2, H_2S, HCl

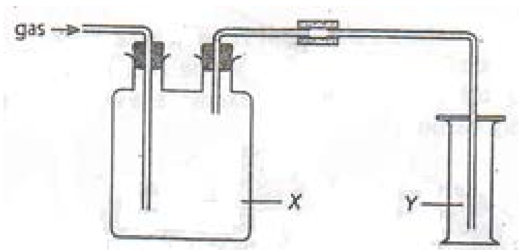
B. HCl, H_2S, N_2

C. H_2S, HCl, N_2

D. HCl, N_2, H_2S

Answer B.

13. The apparatus shown was used to collect a dry gas.



The substances X and Y are respective

A. conc. H_2SO_4 acid and NH_3

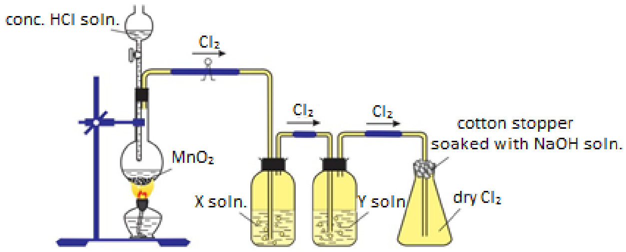
B. conc. H_2SO_4 acid and CO_2

C. H_2O and CO_2

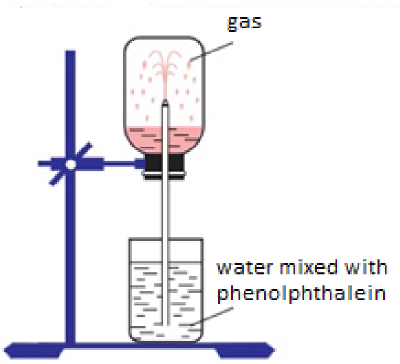
D. H_2O and NH_3.

Answer B.

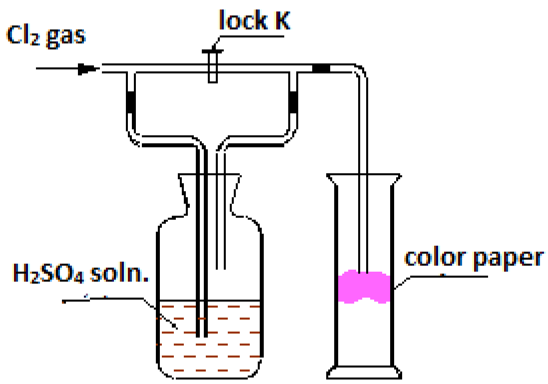
14. In the laboratory, chlorine gas is often prepared from MnO_2 and concentrated HCl acid [5]. To collect clean and dry chlorine gas, obtained gas can go through the gas washing bottles containing X and Y solution as shown below.



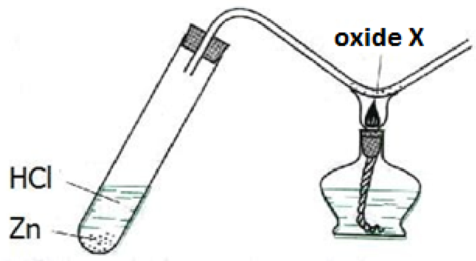
The solutions of X and Y are respective
A. saturated NaCl soln. and conc. H_2SO_4 acid
B. NaOH soln. and conc. H_2SO_4 acid
C. conc. H_2SO_4 acid and saturated NaCl soln.
D. conc. H_2SO_4 acid and NaOH soln.
Answer A.
15. The apparatus is installed to test solubility of a gas as shown below [13]. In downward gas flask, pink water sprayed onto can be seen. Gas in the flask is



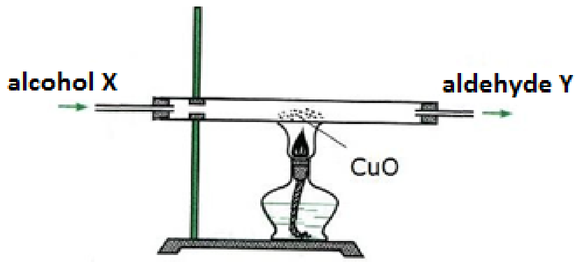
A. HCl
B. NH_3
C. H_2S
D. N_2
Answer B.
16. In the experiment below, fresh chlorine gas, which was prepared from solid manganese dioxide and concentrated hydrochloric acid solution, passed into a cylindrical tube with a piece of color paper.



Which of the following statements is true?
A. When the K is closed, the color paper will lose its color, when K is unlocked, the color paper will not lose its color.
B. When the K is closed, the color paper is not discolored, when K is unlocked, the color paper becomes discolored.
C. When K is unlocked, the color paper turns pink.
D. When K is unlocked, the color of the paper does not change.
Answer B.
17. The following figure describes the experiment to prepare metal by using hydrogen gas to reduce metal oxide [9,10,11].



X appropriate oxides may be
A. MgO and K_2O.
B. Fe_2O_3 and CuO.
C. Na_2O and ZnO.
D. Al_2O_3 and BaO.
Answer B.
18. Vapour of alcohol X is passed through a porcelain tube containing powder of CuO heated as the shown figure below [12].



Two alcohols not satisfied with the properties of X are
A. ethanol and propan-1-ol.
B. propan-1-ol and propan-2-ol.
C. methanol and ethanol.
D. propan-2-ol and butan-2-ol.
Answer D.

3. Conclusion

Currently chemistry experimental exercises are not used a variety of teaching chemistry in high school by teachers and students because the existing resource are not as rich as other types of exercise. The reason is the complexity of content exercise that associated with the experiment and often used experimental images and simulation experiments to illustrate. Above are some illustration applications to design for chemistry experimental exercises, this way, teachers can design for much more, meeting the needs of teaching chemistry in the direction of development thinking and training practical skills in high school [6,7].

Competing Interest

The authors declare no competing financial interest.

Acknowledgments

We thank the anonymous reviewers of this paper for many very helpful suggestions.

References

[1] Bennett S. and O'Neale K., (1998), Skills development and practical work in chemistry, Univ. Chem. Educ., 2, 58-62.

[2] Michael K. Seery, Hendra Y. Agustian, Euan D. Doidge, Maciej M. Kuchaski, Helen M. O'Connor and Amy Price (2017), Developing laboratory skills by incorporating peer-review and digital badges, Chem. Edu. Res. Pract..

[3] Millar R.. (2004). The role of practical work in the teaching and learning of science, High school science laboratories: role and vision, Washington DC, USA: National Academy of Sciences, pp. 1-24.

[4] Neeland E. G., (2007), A One-Hour Practical Lab Exam for Organic Chemistry, J. Chem. Educ., 84(9), 1453.

[5] Scheele (1774) "Om brunsten, eller magnesia, och dess egenskaper" (On manganese or magnesia, and its properties), *Kongliga Vetenskaps Academiens Handlingar* (Proceedings of the Royal Scientific Academy [of Sweden]), 35: 89-116. On pages 93-94 (paragraph 6), "Med den vanliga Salt-syran." ([Reactions of manganese dioxide] with the standard salt-acid [i.e., hydrochloric acid]), Scheele describes a gas (chlorine) that was produced when he reacted manganese dioxide with hydrochloric acid. Further experiments with chlorine appear in paragraphs 23-26, pages 105-110.

[6] Reid N. and Shah I.. (2007). The role of laboratory work in university chemistry, Chem. Educ. Res. Pract., 8(2), 172-185.

[7] Rhodes M. M.. (2010). A Laboratory Practical Exam for High School Chemistry, J. Chem. Educ., 87(6), 613-615.

[8] This experiment has been reproduced from Practical Chemistry: http://www.practicalchemistry.org/standard-techniques/generating-collecting-and-testinggases, 52, AR.html.

[9] J. Bessières, A. Bessières, J.J. Heizmann. (1980). Iron oxide reduction kinetics by hydrogen. International Journal of Hydrogen Energy, Volume 5, Issue 6, 1980, pp. 585-595.

[10] Fathi Habashi, editor. (1997). Handbook of Extractive Metallurgy, Volume III (Weinheim, Germany: Wiley VCH, 1997).

[11] A. Agrawal et al.. (2006). "A Comprehensive Review on the Hydrometallurgical Process for the Production of Nickel and Copper Powders by Hydrogen Reduction," Materials Research Bulletin, 41 (2006), pp. 879-892.

[12] Hariharan Rajesh, Umit S. Ozkan. (1993). Complete oxidation of ethanol, acetaldehyde and ethanol/methanol mixtures over copper oxide and copper-chromium oxide catalysts. *Ind. Eng. Chem. Res.*, 1993, *32* (8), pp 1622-1630.

[13] Purnendu K. Dasgupta, Shen Dong. (1986). Solubility of ammonia in liquid water and generation of trace levels of standard gaseous ammonia. Atmospheric Environment, Volume 20, Issue 3, 1986, pp. 565-570.