Hydrogen in the redox potential list - the standard hydrogen electrode (Item No.: P1148400)

Curricular Relevance

Area of Expertise: Chemistry

Education Level: Age 16-19

Topic: Physical chemistry

Subtopic: Electrochmistry, potentials, conductivity and electrolysis

Experiment: Hydrogen in the redox potential list - the standard hydrogen electrode

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	1 Student

Additional Requirements:

Experiment Variations:

Keywords:

Task and equipment

Tasks

1. Redox series with iron, copper, lead and hydrogen
2. Preparation of a standard hydrogen electrode
3. Voltage measurement against a standard hydrogen electrode

Note

Only dilute silver nitrate is used in the experiment because of cost. The electrode potential according to the Nernst equation is correspondingly lower.

Data

Table 1: Molar masses

Substance	Molar mass [g/mol]
$ZnSO_4 \cdot 7\ H_2O$	287.54
$AgNO_3$	169.87

Table 2: Standard potentials

Electrode pair	Standard potential E^o [V]
Zn/Zn^{2+}	-0.763
Ag/Ag^{2+}	+0.799

Equipment

Position No.	Material	Order No.	Quantity
1	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
2	Right angle boss-head clamp	37697-00	2
3	Universal clamp	37715-00	2
4	Tripod,ring d=140 mm, h=240 mm	33302-00	1
5	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
6	Test tube,200x30 mm	36304-01	3
7	Test tube rack, wood, for 6 tubes d= 30 mm	40569-10	1
8	Receptacle for half-cell, PN29	44452-00	2
9	Silicone tubing i.d. 7mm, 1 m	39296-00	1
10	Platinum electrode in protection tube, d = 8 mm	45206-00	2

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11	Glass tube w.hook, 160+15 mm	36701-17	2
12	Bar electrode, Zinc, d=8mm, l=100mm	45288-02	1
13	Contact socket f.bar electrodes	45283-00	1
14	Alligator clips, insulated, black, 10 pcs.	07276-15	1
15	Rubber stopper 26/32, 3 holes 7 mm	39258-03	2
16	PHYWE power supply, universal DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5 A	13504-93	1
17	PHYWE Demo Multimeter ADM 3: current, voltage, resistance, temperature	13840-00	1
18	Connecting cord, 32 A, 500 mm, red	07361-01	1
19	Connecting cord, 32 A, 500 mm, blue	07361-04	2
20	Beaker, Borosilicate, tall form, 50 ml	46025-00	1
21	Beaker, Borosilicate, tall form, 250 ml	46027-00	4
22	Volumetric flask 1000ml, IGJ24/29	36552-00	2
23	Wash bottle, plastic, 500 ml	33931-00	1
24	Spoon, special steel	33398-00	1
25	Glass rod,boro 3.3,l=300mm, d=7mm	40485-05	1
26	Rubber tubing, i.d. 6 mm	39282-00	2
27	Hose clip, diam. 8-16 mm, 1 pc.	40996-02	3
28	Steel cylinder hydrogen, 2 l, full	41775-00	1
29	Reducing valve for hydrogen	33484-00	1
30	Table stand for 2 l steel cylinders	41774-00	1
31	Wrench for steel cylinders	40322-00	1
32	Tubing connector,Y-shape, ID 8-9mm	47518-03	1
33	Pinchcock, width 15 mm	43631-15	1
34	Teclu burner, DIN, natural gas	32171-05	1
35	Safety gas tubing, DVGW, sold by metre	39281-10	1
36	Hose clip f.12-20 diameter tube	40995-00	2
37	Lighter f.natural/liquified gases	38874-00	1
38	Precision Balance, Sartorius ENTRIS623-1S, 620 g / 0.001 g	49294-99	1
39	Weighing dishes, square shape, 84 x 84 x 24 mm, 25 pcs.	45019-25	1
40	Pasteur pipettes, 250 pcs	36590-00	1
41	Rubber caps, 10 pcs	39275-03	1
42	Scissors, straight,180 mm	64798-00	1
43	Potassium nitrate 250 g	30106-25	1
44	Zinc sulphate 7-hydr. 250 g	30249-25	1
45	Platinum wire, d 0.3 mm, 100 mm	31739-03	1
46	Silver foil, 150 x150 x 0.1 mm, 25 g	31839-04	1
47	Iron powder, techn. 500 g	30067-50	1
48	Copper, powder 100 g	30119-10	1
49	Lead, granular 250 g	30040-25	1
50	Caustic soda solution, 1.0 m, 1000 ml	48329-70	1
51	Hydrochloric acid, 1.0 mol/l, 1000 ml	48454-70	1
52	Nitric acid , 65% 1000 ml	30213-70	1
53	Hydrochloric acid 37 %, 1000 ml	30214-70	1
54	Glycerol, 250 ml	30084-25	1
55	Water, distilled 5 l	31246-81	1
56	Clay pins, d = 8 mm, l = 15 mm, 2 pcs.	32486-00	1

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Safety information

Concentrated acids and bases cause severe burns. They destroy skin and textiles. When diluting: First water, then acid (protective goggles, laboratory coat, gloves).

First aid
After contact with skin, eyes with open eyelids, textiles etc., wash off with plenty of water. Seek medical advice immediately on eye injury.

Waste disposal
Collect solutions that contain heavy metals in a container labelled for waste heavy metal solutions.
Collect waste containing silver separately. Dilute residual acids and bases with water, neutralize them (pH 6-8) and wash to drain.

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Set-up and procedure

Task 1

Fill each of three test tubes about halfway up with dilute hydrochloric acid. Put a spatula tip of powdered iron in test tube 1, about the same amount of powdered copper in test tube 2 and of granulated lead in test tube 3.

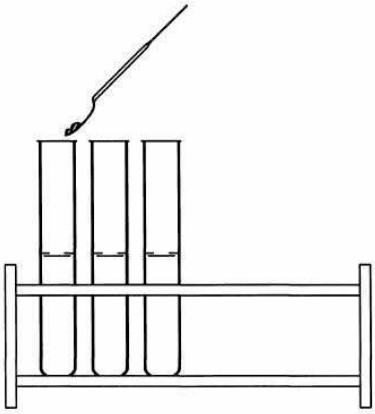

Fig. 1

Task 2

Fill each of three test tubes about halfway up with dilute hydrochloric acid. Put a spatula tip of powdered iron in test tube 1, about the same amount of powdered copper in test tube 2 and of granulated lead in test tube 3.

When the two platinum electrodes are equally blackened ("platinum black"), stop electrolysis and thoroughly rinse the electrodes with water.
Connect the two vessels for the half-cells with tap and side arm together, using a piece of tubing (7 mm i.d.) in which there is a clay pin. This clay pin must be previously well soaked in a potassium nitrate solution. To achieve this, boil it in a cold-saturated potassium nitrate solution for 2 to 3 minutes and then allow it to cool. The clay pin now sucks itself full of potassium nitrate solution. It is preferable to leave the prepared clay pin in this solution until it is to be used.

Fix the half-cells to the rod of the H-base with clamps and boss heads. Fill one of the vessels with 1 molar hydrochloric acid, the other with 1 molar sodium hydroxide, both freshly prepared from ready-made ampoules. Dip a hydrogen electrode into each solution. Prepare the hydrogen electrodes from rubber bungs, the platinised platinum electrodes and a glass tube with a hook (lubricate the glass tube with glycerol so that it can be more easily eased through the bung) which enables hydrogen to bubble over the surface of the platinum foil (see Fig. 2).

After connection of the glass tube with hook to a source of hydrogen (steel cylinder), allow a slow flow of hydrogen to bubble over the platinum foils. Adjust the flow of gas through the V-shaped connection piece (hose clip), so that approximately the same amount of gas flows from each of the glass tubes. The connection of the electrodes to the pH meter (set to the "mV" operating mode, pay attention to polarity) enables the voltage to be measured.

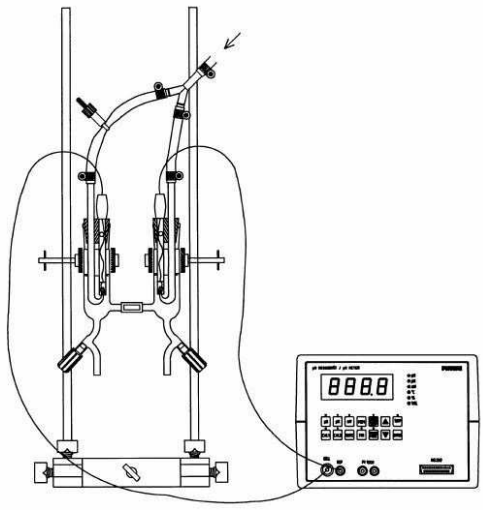

Fig. 2

Task 3

In the second experiment and with the set up shown in Fig. 2, the half-cell containing sodium hydroxide is first to be emptied via the tap and then be thoroughly rinsed with water. Now fill it with a 1 molar zinc sulphate solution containing 57.51 g of zinc sulphate heptahydrate in 200 ml of water. Firmly hold the zinc electrode in a bored-through rubber bung and dip it into the solution. Remove the Y-distributor piece from the feed line to the second platinum electrode and again bubble hydrogen over the electrode in hydrochloric acid. Measure the potential between the two electrodes (observe the polarity!).
Subsequently replace the zinc sulphate solution by a silver nitrate solution (empty out the zinc sulphate solution via the tap and rinse the vessel well with water) and the zinc electrode by a silver foil. After ensuring that the polarity is correct, determine the potential difference between the hydrogen electrode and the silver electrode.

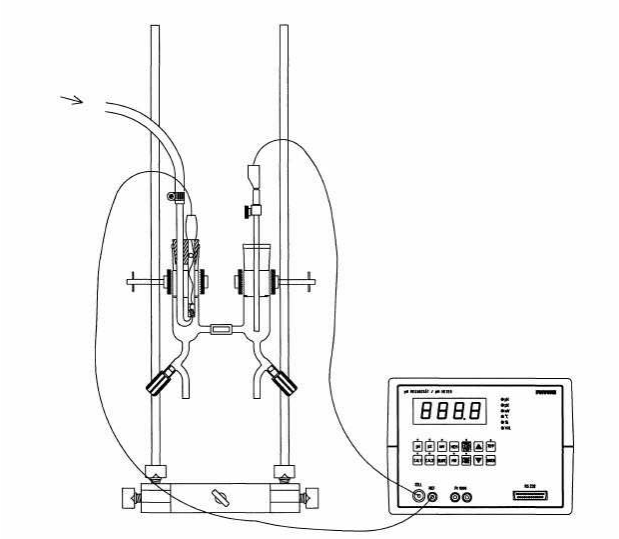

Fig. 3

Observation and evaluation

Observation

Task 1

Whereas evolution of gas immediately starts in test tube 1, it does not occur even after some time in test tube 2 and only weakly in test tube 3.

Task 2

The voltage between the two half-cells is roughly 0.8 to 0.85 V, but when several measurements are made, it will be seen that there are great fluctuations between individual measurements.

Task 3

The potential difference between the zinc half-cell and the standard hydrogen electrode is about 0.7 V to 0.76 V, whereby zinc is connected to the positive pole of the measuring instrument. The values obtained from several measurements are subject to fluctuation.

A voltage of approx. 0.8 V is given between hydrogen and silver with hydrogen as positive pole.

Evaluation

Task 1

Iron and lead reduce hydrogen ions to hydrogen, whereby they themselves are oxidized and go into solution as ions. These two metals are so less noble than hydrogen. The weak evolution of gas in the reaction between lead and hydrochloric acid indicates that the driving force for the reaction, the difference in potential between hydrogen and lead, is small.
Copper is nobler than hydrogen. It is not attacked by hydrochloric acid (as recognisable by the lack of gas evolution, as well as by the lack of colouration of the solution by copper ions).
Hydrogen therefore has a position between copper and lead in the oxidation-reduction potential list

Task 2

The standard hydrogen electrode is defined as being a platinised platinum foil (or wire), that is dipped into a solution with a hydrogen ion activity of 1 and the surface of which is bubbled over by hydrogen under standard pressure (1013 hPa). The platinising of the platinum electrode increases the electrode surface and so improves the contact with hydrogen. The potential of any hydrogen electrode is given by:

$$E_{\mathrm{H}} = \frac{RT}{F} \cdot ln \frac{a_{H^+}}{\sqrt{p_{H_2}}}$$

A different potential results when the hydrogen ion activity is reduced. In caustic soda, for example, the potential is less than that of a standard hydrogen electrode because of the lower hydrogen ion activity or concentration c (H^+) = 10^{-14} mol/l. The calculated potential difference (= voltage) at 25°C is, using the above equation, 0.836 V. As, because of various effects and despite platinising, it is difficult to bring a hydrogen electrode to give reproducible potentials, the measured values are subject to large fluctuations.

Task 3

According to definition, the standard hydrogen electrode has a standard potential of 0 V. The potential of the zinc electrode as electron supplier (zinc goes into solution as zinc ions) is negative compared to the hydrogen electrode and is about -0.76 V. Silver is electropositive compared to hydrogen, i.e. hydrogen goes into solution as a proton after splitting off an electron and so forms the positive pole (anode) of this galvanic element.

The major reason for the fluctuations in the measured values is that it is difficult to reproduce the potential of the hydrogen electrode. Because of this, other reference electrodes are nowadays usually used. Their potential relative to the standard hydrogen electrode must, however, be first be determined in measurement set ups that require much expenditure.

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